



TYPE **1862-B**

MEGOHMMETER

G E N E R A L R A D I O C O M P A N Y

OPERATING INSTRUCTIONS

6625-553-0386

XD2 \$55.00

TYPE 1862-B

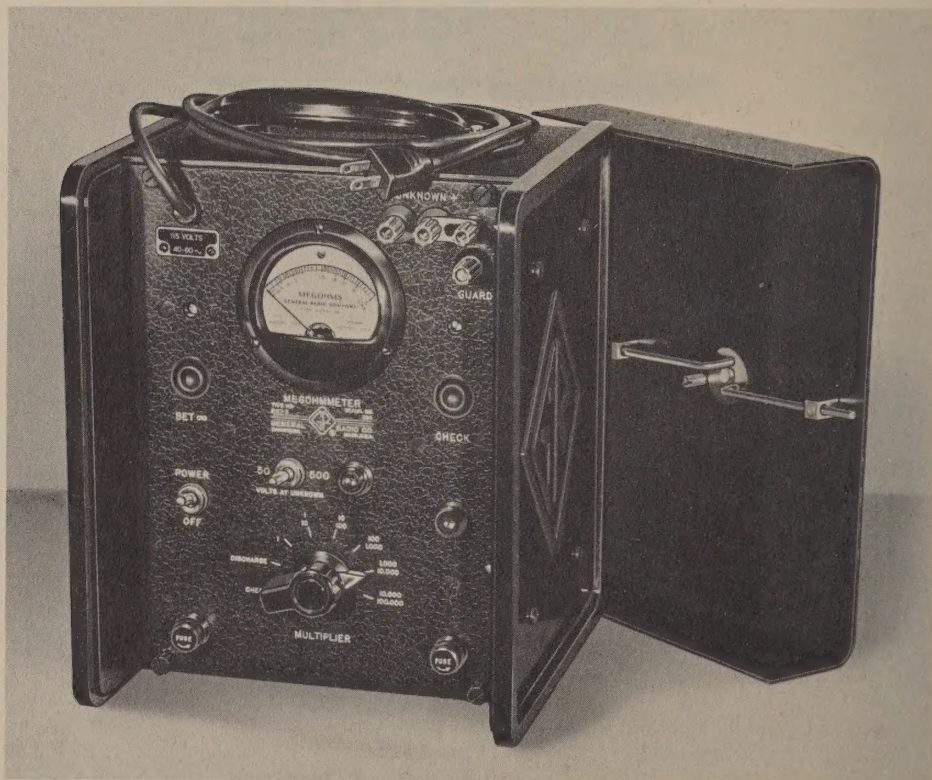
MEGOHMMETER

Form 755-G

June, 1959

G E N E R A L R A D I O C O M P A N Y

WEST CONCORD, MASSACHUSETTS, USA



Panel View of the Type 1862-B Megohmmeter
(For Specifications, see back of foldout.)

TYPE 1862-B MEGOHMMETER

The Type 1862-B Megohmmeter is designed to indicate directly on the panel meter the resistance value of any resistor within the range of 0.5 to 2,000,000 megohms. The voltage applied to the unknown resistance is 500 volts within 10 volts, or 50 volts within 4 volts.

SECTION 1.0 OPERATING CONTROLS AND PROCEDURE

1.1 CAUTION - DANGER

When the instrument is on, there is a potential of 500 volts at the terminals except when the MULTIPLIER switch is set to CHECK or DISCHARGE or when the panel switch is at 50 volts.

1.2 POWER SUPPLY

The instrument is supplied complete, with tubes installed, and is ready for operation.

The power-line voltage and frequency are indicated on the panel label near the power input cable. The voltage is either 115 volts or 230 volts. To change from one input voltage to the other, see Paragraph 2.1 below.

1.3 VOLTAGE AT UNKNOWN

The voltage applied to the unknown is either 50 volts or 500 volts as selected by means of a panel switch. A neon lamp warns when 500-volt operation has been selected.

1.4 CONNECTIONS OF UNKNOWN

Strap the ground terminal to the GUARD terminal or to the adjacent UNKNOWN terminal.

With the MULTIPLIER switch at DISCHARGE, the meter should read ∞ (full counter-clockwise position of the meter pointer). If it does not, adjust the

GENERAL RADIO COMPANY

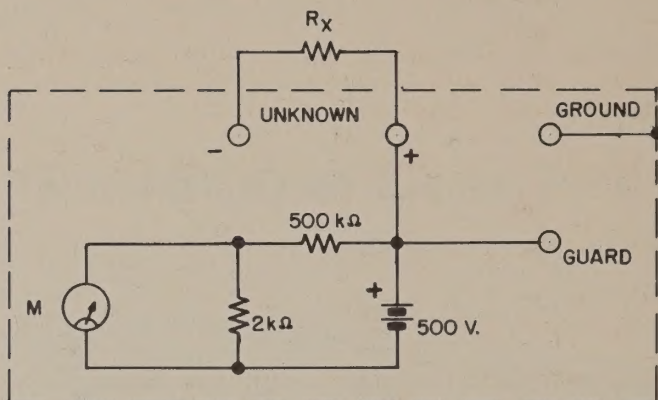


Figure 1. "Check" position of multiplier, with voltage switch at 500 volts.

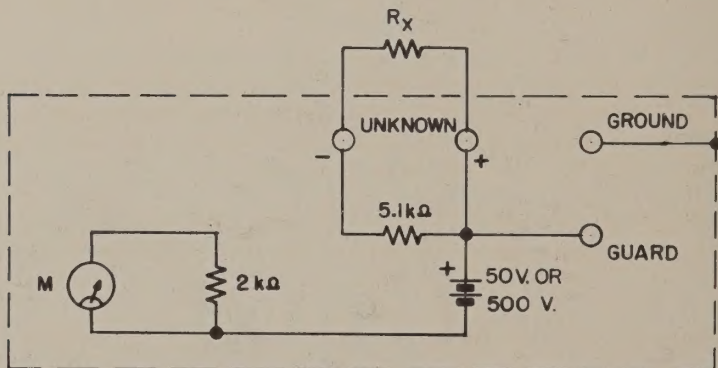


Figure 2. "Discharge" position of multiplier.

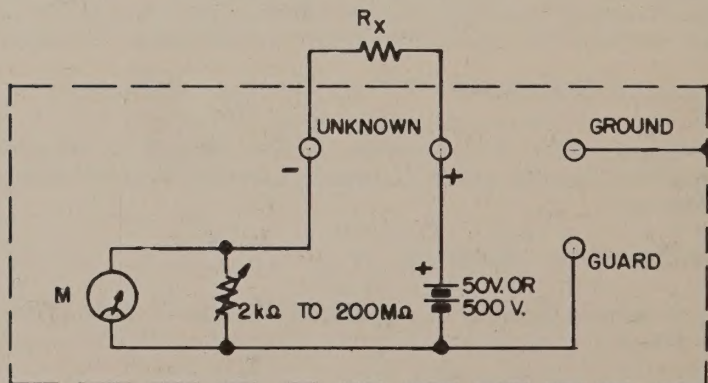


Figure 3. Operating position of multiplier.

TYPE 1862-B MEGOHMMETER

SET ∞ control to obtain an ∞ reading of the meter. As the MULTIPLIER switch is turned to the operating positions, the meter should continue to read ∞ . If it does not, see paragraph 2.3 below.

For a discussion of the CHECK position and of the GUARD and ground terminals, see Section 2.0 below.

The instrument is designed for operation with the panel in a horizontal position.

1.5 RESISTANCE INDICATION

With the MULTIPLIER switch at DISCHARGE, connect the unknown resistance to the UNKNOWN terminals. Move the MULTIPLIER switch to the "1" position. If the meter indicates beyond full scale (0.5), the resistance is less than 0.5 megohm and cannot be measured with this instrument. Return the MULTIPLIER switch to the DISCHARGE position immediately. If the meter indicates on scale, select the MULTIPLIER position that yields a meter reading between 0.5 and 5.

The resistance value is the product of the meter reading and of the MULTIPLIER setting. Read the MULTIPLIER positions indicated in white numerals when the operating voltage selected is 50 volts; read the positions indicated in red numerals when 500 volts has been selected.

CAUTION: Return the MULTIPLIER to the DISCHARGE position before attempting to disconnect the resistor from the UNKNOWN terminals.

SECTION 2.0 SECONDARY CONTROLS AND PROCEDURE

2.1 POWER SUPPLY

The power-line frequency range is 40 to 60 cycles. The voltage is either 115 volts or 230 volts. If it is desired to change from one input voltage to another, change the power transformer connections as shown on the wiring diagram, reverse the power-line label (near the power input cable) to indicate the proper line voltage and change the fuses (on the panel) to the proper rating (0.4 ampere Slo-Blo 3AG fuses for 115-volt operation and 0.2 ampere Slo-Blo 3AG fuses for 230-volt operation). For access to the power transformer connections, remove the instrument from its cabinet.

2.2 TERMINALS

In addition to the insulated terminals to which the UNKNOWN resistance is connected, there is an insulated terminal labeled GUARD and an uninsulated ground terminal which is connected to the panel and which includes a strap for grounding either the GUARD terminal or the adjacent (positive) UNKNOWN terminal. In the operating positions of the MULTIPLIER switch, there is a poten-

GENERAL RADIO COMPANY

tial of 500 volts (or 50 volts) between the GUARD terminal and the positive UNKNOWN terminal. Therefore, do not ever connect these two terminals together.

For most applications, strap the ground terminal to the adjacent UNKNOWN terminal. The polarity at this terminal is positive and is so indicated.

If the unknown resistor is a three-terminal type, it can be measured by connecting the third terminal to GUARD and by grounding the GUARD terminal or the positive UNKNOWN terminal, as shown in Figure 4 and Figure 5, provided that the resistances of the second and third resistors in the network are sufficiently large. R_B is connected directly across the internal standard, R_S , and must be at least one hundred times as large as R_S . At 500-volt operation, R_S is 2 k Ω times the MULTIPLIER setting (red numerals). At 50-volt operation, it is 20 k Ω times the MULTIPLIER setting (white numerals). R_C is connected directly across the internal power supply and must be at least one megohm for 500-volt operation and at least ten megohms for 50-volt operation.

CAUTION: Do not maintain a short-circuit at the UNKNOWN terminals. While a momentary short-circuit will do no damage, a prolonged short-circuit at the two lower ranges can draw excessive current from the high-voltage power supply and will shorten the life of the rectifier and regulator tubes (V-4 and V-5). At the higher multiplier ranges (100, 1000, 10,000 and 100,000), for 500-volt operation, the short-circuit current is 2500, 250, 25, and 2.5 μ a, respectively, and will do no harm. At all ranges, the panel meter current at short-circuit condition is about 500 μ a. The normal full-scale rating is 200 μ a.

2.3 CHECK AND DISCHARGE POSITIONS

With the MULTIPLIER switch in either of these positions, there is no voltage at any of the terminals; in the DISCHARGE position, the UNKNOWN terminals are shunted with a 2-watt, 5.1 k Ω resistor (R-2).

With the switch at DISCHARGE, the meter should indicate ∞ . If it does not, adjust the SET ∞ control.

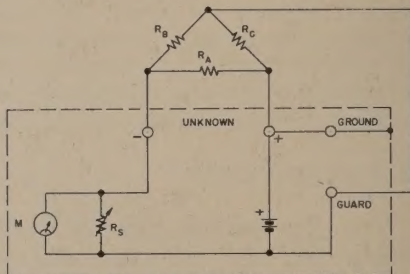
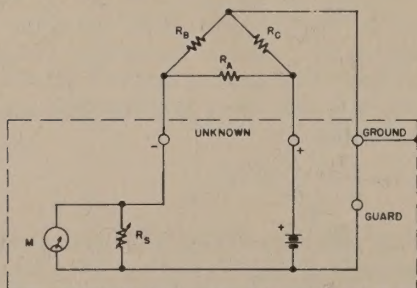


Figure 4. Connections for measuring ungrounded three-terminal resistor.

Figure 5. Connections for measuring grounded three-terminal resistor.

TYPE 1862-B MEGOHMMETER

As the MULTIPLIER switch is rotated through the operating positions, the meter will continue to indicate ∞ if nothing is connected to the UNKNOWN terminals. If there is a meter indication at the next-highest setting, this can be caused by leakage or by grid current in the voltmeter tube (V-1). Leakage due to moisture or dirt can be eliminated by wiping the UNKNOWN terminals with a clean dry cloth. Grid-current effects can occur when V-1 has been replaced with a new tube or when the instrument has not been used for some time. The grid-current effect will be eliminated or reduced to a negligible value (a meter reading that is less than halfway between ∞ and 20 is considered negligible) by leaving the instrument on for a short while. (See 3.0 under Service and Maintenance Notes.) If there is no meter indication at the lower multiplier settings, but an indication appears at the highest setting, reset to ∞ by adjusting the screw-driver control accessible through a small panel hole just above the SET ∞ knob.

When the MULTIPLIER is set to the CHECK position and the voltage switch is at 500 volts, an internal resistance standard is connected in circuit. The meter should read 0.5. If it does not, readjust the CHECK control knob.

2.4 FIVE-HUNDRED-VOLT SUPPLY

In the 500-volt operating position, there is a potential of 500 volts between the positive UNKNOWN terminal and the GUARD terminal. If, because of tube changes or any other reason, this voltage, as measured by a voltmeter of at least 1 M Ω resistance, is found to be incorrect, it can be adjusted by setting the screw-driver control accessible through a small panel hole just above the CHECK control knob. If this screw-driver control is reset, the megohmmeter calibration must be standardized by again setting the MULTIPLIER to CHECK and obtaining a 0.5 (or CHK) reading on the meter, readjusting the CHECK control knob if need be.

2.5 FIFTY-VOLT SUPPLY

After the 500-volt supply has been standardized as described above, the 50-volt supply can be checked and adjusted if necessary. For the 50-volt operating position, there must be a potential of 51 volts between the positive UNKNOWN terminal and the GUARD terminal when measured with a meter of 10 megohms or more resistance (49.7 volts with a one-megohm meter). If the voltage is not correct, it can be adjusted by resetting, with a screw-driver, the voltage divider mounted inside the instrument on the left-hand side of the shelf (R-35).

2.6 RESISTANCE OF CAPACITORS

The leakage resistance of capacitors is measured in exactly the same manner as the resistance of resistors except that the charge- and discharge-currents involved require some precaution.

2.61 Always short-circuit the capacitor for several seconds before connecting to the megohmmeter, to assure that it has no dangerous residual charge.

GENERAL RADIO COMPANY

2.62 Always start the MULTIPLIER at the DISCHARGE position.

2.63 Always set the MULTIPLIER at the "1" position for a few seconds to assure rapid charge of the capacitor. To prevent damage to the meter, do not set the MULTIPLIER to higher values until the capacitor is well charged.

2.64 When the measurement has been completed, discharge the capacitor by setting the MULTIPLIER to DISCHARGE for several seconds before disconnecting the capacitor. In the DISCHARGE position, the capacitor is discharged by the 5.1-k Ω , 2-watt resistor (R-2) which appears in shunt at the UNKNOWN terminals.

2.7 CHARGING TIME

Since the panel meter reading of the megohmmeter depends on the current through the unknown resistor, the leakage resistance of a capacitor or of an insulator cannot be correctly indicated until the charging current due to the capacitive component is negligible.

When the capacitor has very little dielectric absorption, the charging current is limited mainly by the resistance standard in the megohmmeter. In the lowest multiplier position, this resistance is 2000 ohms and for even large capacitance values the charging time is relatively small, being of the order of one second per hundred microfarads.

Many capacitors and most insulators (especially those of laminated structure) exhibit appreciable dielectric absorption (dipole and interfacial polarization). When a voltage is applied, the charge slowly diffuses throughout the volume and it may require minutes or hours (even days in some special cases) before equilibrium is established and the charging current is small compared to the true leakage current.

2.8 INSULATION TESTING

In testing the insulation of electrical machinery, transformers, etc., while the leakage resistance is important, it is only one of several parameters that have a bearing on the condition of the insulation. Routine measurements of capacitance and dissipation factor as well as leakage resistance provide useful data in monitoring the condition of the insulator and in guarding against incipient breakdown.

A routine test that has been fairly widely adopted in the insulation-testing field consists of measuring the apparent leakage resistance after a testing voltage of 500 volts has been applied for one minute and again for ten minutes. The ratio of the indicated resistances, sometimes referred to as the polarization index, can have some relation to the condition of the insulator. The results of course are really a measure of the charging current at the two time intervals and can be much more dependent on the dielectric absorption of the insulator

TYPE 1862-B MEGOHMMETER

than on its true leakage resistance. To extend the usefulness of such information, complete charge-current vs. time data should be obtained.¹

The Type 1862-B Megohmmeter is useful in measuring the true leakage resistance by the method outlined in Paragraph 2.6 above and in measuring the apparent leakage at the end of one-minute and ten-minute intervals.

The resistance in series with the insulator during the charging period is determined by the setting of the MULTIPLIER control; it is the product of the red MULTIPLIER reading and 2000 ohms when the applied voltage is 500 volts.

The charge current is easily measured when the meter is on scale; the charge current is the applied voltage divided by the apparent resistance at any moment; the meter will be off scale at the start of the charge-current vs. time characteristic.

2.9 TEST LEADS AND ACCESSORIES

Two rubber-covered test leads, one red and one black, are supplied. Each is 36 inches long and has a banana plug at one end and an alligator clip at the other. Although these test leads are adequate over most of the resistance range, measurements of very high resistance may require shorter leads or even shielded leads, depending on the physical size of the component under test and on the ambient field conditions.

There is capacitance from the high UNKNOWN lead to ground, to the other lead, and even to the operator. If the lead is suddenly displaced or if the operator waves his hand in the vicinity of the lead, the resultant capacitance change will be accompanied by a momentary fluctuation in the meter reading.

CAUTION

When using the test leads, remember that there can be 500 volts between them.

3.0 SHOCK HAZARD

Every precaution has been taken in the design of the Type 1862-B Megohmmeter to reduce the possibility of shock. However, the operator should be aware of the dangers involved because of the high voltages present. The resistance to current depends, of course, on humidity conditions. From arm to arm, leg to arm, leg to leg, it can be as low as 300 ohms but under some circumstances it can be as high as one megohm. At low voltages, the skin offers a fair protection but at higher voltages, the skin is burned, its resistance is lowered and the low internal body resistance is controlling.

¹ "The Basis for the Nondestructive Testing of Insulation," R.F. Field, AIEE Transactions, September, 1941. "Interpretation of Current-Time Curves as Applied to Insulation Testing," R.F. Field, Boston District Meeting AIEE, April 19-20, 1944.

GENERAL RADIO COMPANY

When the MULTIPLIER switch of the Type 1862-B Megohmmeter is in an operating position, touching the two UNKNOWN terminals with one finger is painful and can cause a slight burn. The amount of direct current that will flow, at 500-volt operation, for various values of "body" resistance connected from the GUARD terminal to the positive UNKNOWN terminal is shown plotted in Figure 6. Currents due to connection to the UNKNOWN terminals will always be less; the value depends on the setting of the MULTIPLIER switch. See CAUTION under Paragraph 2.2. Since the lethal value depends on the individual and on humidity conditions, extreme caution must be observed at all times.

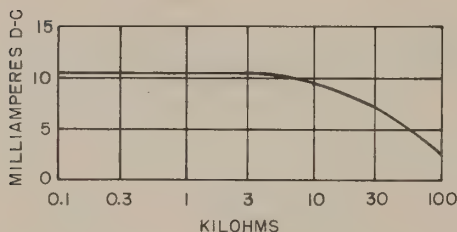


Figure 6. Current due to a load from GUARD to positive UNKNOWN terminals for 500-volt operation.

When a large capacitor is connected to the UNKNOWN terminals, it should be treated with great caution because there can be 500 volts at its terminals and it may have no appreciable inherent current-limiting series resistance. The current that will flow through the body upon connecting the "body resistance" to its terminals will at first be very great and the speed with which the current is damped depends on the capacitance as well as the resistance. A current-limiting resistor of one megohm should be connected as near to the capacitor as possible. Current decay curves for various values of capacitance and of "body resistance" are shown in Figure 7.

3.1 VOLTAGE COEFFICIENT OF RESISTORS

The resistance of some small resistors and of many insulators is affected by the voltage applied. A voltage coefficient of -0.05 percent per volt is not unusual. At 500 volts, if the coefficient is -0.05 percent, the resistance will be lower than its "zero volts" value by 25 percent. If the unknown is measured at 500 volts and then at 50 volts, the voltage coefficient of resistance can be calculated.

3.2 RESISTANCE AT OTHER VOLTAGES ACROSS UNKNOWN

If an adjustable power supply (such as the General Radio Type 1204-B Unit Variable Power Supply) and an accurate d-c voltmeter are available, they can be used with the Type 1862-B Megohmmeter to measure resistance with any value less than 500 volts applied to the unknown.

The procedure is as follows: Remove V-4 and V-5 (2X2-A and 6AB4) to disconnect the internal 500-volt supply. Set the voltage selector switch to 500

TYPE 1862-B MEGOHMMETER

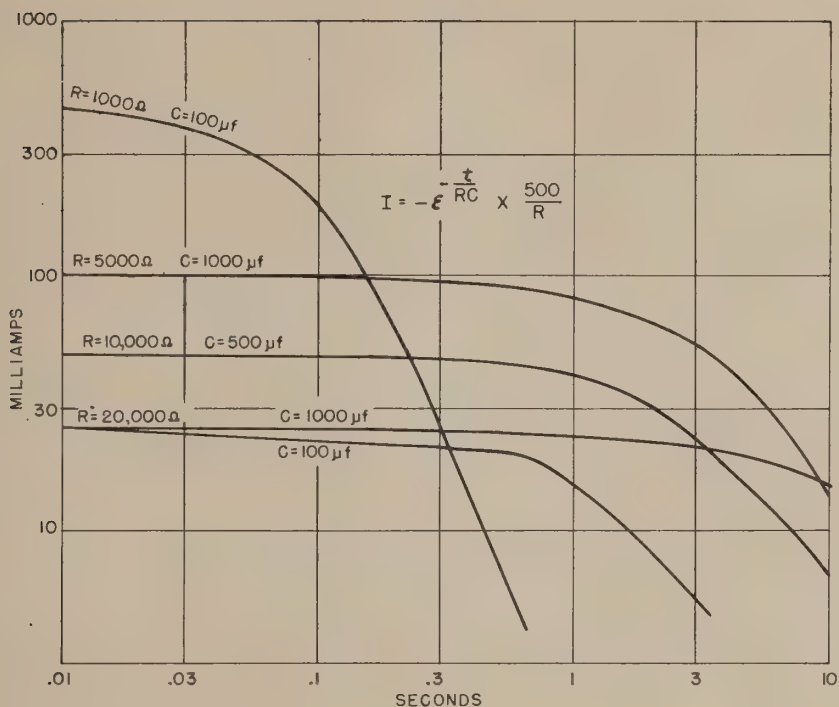


Figure 7. Discharge currents for 500 volts at charge.

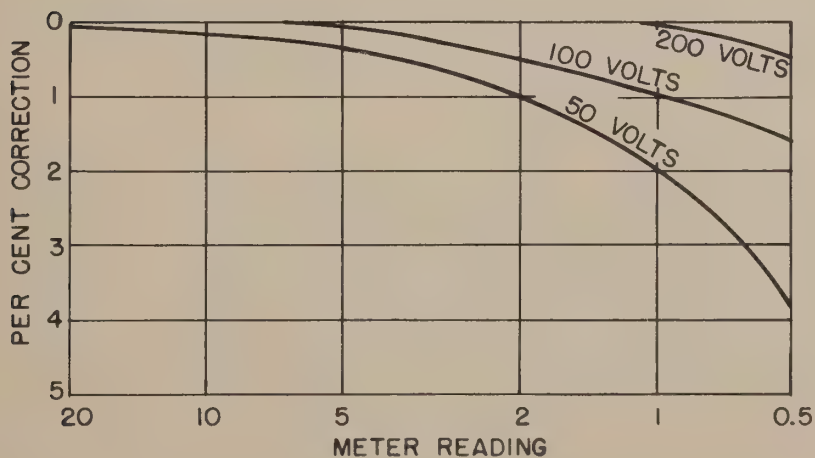


Figure 8. Correction when using external supply. See text.

GENERAL RADIO COMPANY

volts. Connect the external supply (with the external voltmeter across it) to the GUARD (minus) and the positive UNKNOWN terminals.

CAUTION: Do not set to CHECK or DISCHARGE since the power supply will be shorted under these conditions.

Set the external supply to the desired voltage. The resistance of the unknown is then measured in the normal manner using the 500-volt MULTIPLIER readings (red engraving). The resistance of the unknown is

$$R_x = \frac{E}{500} M$$

where E is the voltage from the external supply and M is the resistance indicated by the megohmmeter. If the external voltage is less than 100 volts, the calculated resistance must be reduced by the amount indicated in Figure 8.

SERVICE AND MAINTENANCE NOTES

1.0 INSTRUMENT IN CABINET

- 1.1 At 115-volt (or 230-volt) line, the power input is about 25 watts.
- 1.2 Fuses and pilot light are accessible from the panel.

2.0 INSTRUMENT OUT OF CABINET

- 2.1 All tubes and components are accessible.

2.2 Note that the shaft of the selector switch (S-1) and the switch-mounting screws can be 500 volts above ground. The switch is mounted on a black phenolic plate and the control-knob (MULTIPLIER) set-screw holes are plugged with wax.

3.0 GRID CURRENT

To test for grid current (see 2.3 of Operating Instructions) at 500-volt operation, set to the "1" multiplier and obtain an " ∞ " meter reading, then set to the "10,000" multiplier and obtain a meter reading that is less than halfway between ∞ and 20. A meter reading greater than this indicates excessive grid current or leakage. Leakage is eliminated by cleaning the terminals. Grid current may be excessive if the instrument has not been used for some time; normal operation for ten minutes will reduce the grid current satisfactorily. Grid current may also be excessive if the tube (V-1) has been replaced.

If the tube has been replaced and grid current is excessive even after several minutes of operation, age the tube by leaving the power on for several hours (at least eight). When the indicated grid current is satisfactorily low for the 10,000 multiplier, set to the 100,000 multiplier and obtain an ∞ meter

TYPE 1862-B MEGOHMMETER

reading by adjusting the screw-driver control accessible through a small panel hole just above the SET ∞ knob.

4.0 METER FLUCTUATIONS

If the line voltage is erratic or fluctuates seriously, the meter reading will also fluctuate when measuring the leakage of capacitors unless the 500-volt supply is very well stabilized. The potentiometer, R-33, has been set for almost perfect stabilization. If, however, V-6 or V-7 or particularly V-4 have been replaced, it may be necessary to readjust R-33. This is important only for capacitance leakage measurements. The procedure is simple. A Variac[®] or other means is used to vary the line voltage and R-33 (mounted on the shelf, under the meter) is adjusted for negligible meter variation when the UNKNOWN is a capacitor, (e.g., a mica 10,000 $\mu\mu\text{f}$ with resistance indication on the highest multiplier range).

5.0 VACUUM-TUBE DATA

The following table gives tube-socket voltages measured from socket pin to ground. The data were obtained with the instrument operating under the following conditions: 115-volts, 60-cycle line, ground terminal strapped to GUARD terminal, MULTIPLIER switch at "1", voltage switch at 500, CHECK control full counter-clockwise, SET ∞ control at about the middle of its range.

The d-c voltages were measured with a 20,000-ohm-per-volt instrument whose full-scale ranges were 10 volts, 50 volts, 250 volts, and 1000 volts. D-C voltages can be expected to vary $\pm 20\%$. Tabulated voltages are dc.

Symbol	Type	Socket Pin Number										Function
		1	2	3	4	5	6	7	8	9	Cap	
V-1	12AU7	+55	0	+3	---	---	+55	0	+3	---	---	V-T Voltmeter
V-2	0A2	+55	-90	---	-90	+55	---	-90	---	---	---	B Supply Regulator
V-3	6X4	-90	---	---	---	0	-90	+125	---	---	---	B Supply Rectifier
V-4	2X2-A	+900	+500	---	+900	---	---	---	---	---	+820	500-v Supply Rectifier
V-5	6AB4	+900	+75	---	---	+500	+490	+500	---	---	---	Series Regulator
V-6	6AU6	+85	+88	---	---	+470	+220	+88	---	---	---	Regulator Amplifier
V-7	5651	+88	0	---	0	+88	---	0	---	---	---	Reference Voltage

Parts List for Type 1862-B Megohmmeter

RESISTORS	TYPE	Value	Tolerance	Part of
R-1	REC-30BF	10 Megohms	±10%	POS-11
R-2	REC-30BF	5.1 k Ohms	±5%	POS-11
R-3	REC-30BF	4.3 k Ohms	±5%	REC-30BF
R-4	REC-30BF	3.3 k Ohms	±10%	REC-20BF
R-5	REC-30BF	100 k Ohms	±5%	REC-30BF
R-6	REC-30BF	100 k Ohms	±5%	REC-20BF
R-7	REC-30BF	140 k Ohms	±10%	REC-30BF
R-8	REC-30BF	495 k Ohms	±1/2%	REC-20BF
R-9	REC-30BF	2 k Ohms	±1/2%	REC-30BF
R-10	REC-30BF	20 k Ohms	±1%	REC-30BF
R-11	REC-30BF	200 k Ohms	±1%	REC-30BF
R-12	REC-30BF	2 Megohms	±1%	REC-30BF
R-13	REC-30BF	20 Megohms	±1%	REC-30BF
R-14	REC-30BF	100 Megohms	±1%	REC-30BF
R-15	REC-30BF	100 Megohms	±1%	REC-30BF
R-16	REC-30BF	1 Megohm	±10%	REC-30BF
R-17	REC-30BF	15 k Ohms	±5%	REC-30BF
R-18	REC-30BF	62 k Ohms	±5%	REC-30BF
R-19	REC-30BF	22 k Ohms	±10%	REC-30BF
R-20	REC-30BF	22 k Ohms	±10%	REC-30BF
R-21	REC-30BF	500 Ohms	±10%	REC-30BF
R-22	REC-30BF	330 Ohms	±10%	REC-30BF
R-23	REC-30BF	5.1 k Ohms	±5%	REC-30BF
R-24	REC-30BF	560 k Ohms	±5%	REC-30BF
R-25	REC-30BF	20 k Ohms	±10%	REC-30BF
R-26	REC-30BF	24 k Ohms	±5%	REC-30BF
R-27	REC-30BF	1 Megohm	±10%	REC-30BF
R-28	REC-30BF	22 k Ohms	±5%	REC-30BF
R-29	REC-30BF	22 k Ohms	±10%	REC-30BF
R-30	REC-30BF	100 k Ohms	±10%	REC-30BF
R-31	REC-30BF	100 k Ohms	±10%	REC-30BF
R-32	REC-30BF	15 Ohms	±10%	REC-30BF
R-33	REC-30BF	100 k Ohms	±10%	REC-30BF
R-34	REC-30BF	20 k Ohms	±10%	POS-11
R-35	REC-30BF	25 k Ohms	±10%	POS-11
R-36	REC-30BF	47 k Ohms	±5%	REC-30BF
R-37	REC-30BF	620 Ohms	±5%	REC-20BF
R-38	REC-30BF	2.2 Megohms	±10%	REC-30BF
R-39	REC-30BF	820 Ohms	±5%	REC-20BF
CONDENSERS				
C-1	REC-30BF	.005 μf	±10%	CON-35B
C-2	REC-30BF	.005 μf	±10%	CON-35B
C-3	REC-30BF	.005 μf	±10%	CON-35B
C-4	REC-30BF	.005 μf	±10%	CON-35B
C-5	REC-30BF	20 μf	±10%	CON-35B
C-6	REC-30BF	20 μf	±10%	CON-35B
C-7	REC-30BF	.15 μf	±10%	CON-35B
C-8	REC-30BF	.15 μf	±10%	CON-35B
C-9	REC-30BF	.15 μf	±10%	CON-35B
C-10	REC-30BF	.15 μf	±10%	CON-35B
C-11	REC-30BF	.25 μf	±10%	CON-35B
C-12	REC-30BF	16 μf	±10%	CON-35B
C-13	REC-30BF	150 μf	±10%	CON-35B
C-14	REC-30BF	150 μf	±10%	CON-35B
C-15	REC-30BF	150 μf	±10%	CON-35B
C-16	REC-30BF	150 μf	±10%	CON-35B
C-17	REC-30BF	150 μf	±10%	CON-35B
C-18	REC-30BF	150 μf	±10%	CON-35B
C-19	REC-30BF	150 μf	±10%	CON-35B
C-20	REC-30BF	150 μf	±10%	CON-35B
C-21	REC-30BF	150 μf	±10%	CON-35B
C-22	REC-30BF	150 μf	±10%	CON-35B
C-23	REC-30BF	150 μf	±10%	CON-35B
C-24	REC-30BF	150 μf	±10%	CON-35B
C-25	REC-30BF	150 μf	±10%	CON-35B
C-26	REC-30BF	150 μf	±10%	CON-35B
C-27	REC-30BF	150 μf	±10%	CON-35B
C-28	REC-30BF	150 μf	±10%	CON-35B
C-29	REC-30BF	150 μf	±10%	CON-35B
C-30	REC-30BF	150 μf	±10%	CON-35B
C-31	REC-30BF	150 μf	±10%	CON-35B
C-32	REC-30BF	150 μf	±10%	CON-35B
C-33	REC-30BF	150 μf	±10%	CON-35B
C-34	REC-30BF	150 μf	±10%	CON-35B
C-35	REC-30BF	150 μf	±10%	CON-35B
C-36	REC-30BF	150 μf	±10%	CON-35B
C-37	REC-30BF	150 μf	±10%	CON-35B
C-38	REC-30BF	150 μf	±10%	CON-35B
C-39	REC-30BF	150 μf	±10%	CON-35B
C-40	REC-30BF	150 μf	±10%	CON-35B
C-41	REC-30BF	150 μf	±10%	CON-35B
C-42	REC-30BF	150 μf	±10%	CON-35B
C-43	REC-30BF	150 μf	±10%	CON-35B
C-44	REC-30BF	150 μf	±10%	CON-35B
C-45	REC-30BF	150 μf	±10%	CON-35B
C-46	REC-30BF	150 μf	±10%	CON-35B
C-47	REC-30BF	150 μf	±10%	CON-35B
C-48	REC-30BF	150 μf	±10%	CON-35B
C-49	REC-30BF	150 μf	±10%	CON-35B
C-50	REC-30BF	150 μf	±10%	CON-35B
C-51	REC-30BF	150 μf	±10%	CON-35B
C-52	REC-30BF	150 μf	±10%	CON-35B
C-53	REC-30BF	150 μf	±10%	CON-35B
C-54	REC-30BF	150 μf	±10%	CON-35B
C-55	REC-30BF	150 μf	±10%	CON-35B
C-56	REC-30BF	150 μf	±10%	CON-35B
C-57	REC-30BF	150 μf	±10%	CON-35B
C-58	REC-30BF	150 μf	±10%	CON-35B
C-59	REC-30BF	150 μf	±10%	CON-35B
C-60	REC-30BF	150 μf	±10%	CON-35B
C-61	REC-30BF	150 μf	±10%	CON-35B
C-62	REC-30BF	150 μf	±10%	CON-35B
C-63	REC-30BF	150 μf	±10%	CON-35B
C-64	REC-30BF	150 μf	±10%	CON-35B
C-65	REC-30BF	150 μf	±10%	CON-35B
C-66	REC-30BF	150 μf	±10%	CON-35B
C-67	REC-30BF	150 μf	±10%	CON-35B
C-68	REC-30BF	150 μf	±10%	CON-35B
C-69	REC-30BF	150 μf	±10%	CON-35B
C-70	REC-30BF	150 μf	±10%	CON-35B
C-71	REC-30BF	150 μf	±10%	CON-35B
C-72	REC-30BF	150 μf	±10%	CON-35B
C-73	REC-30BF	150 μf	±10%	CON-35B
C-74	REC-30BF	150 μf	±10%	CON-35B
C-75	REC-30BF	150 μf	±10%	CON-35B
C-76	REC-30BF	150 μf	±10%	CON-35B
C-77	REC-30BF	150 μf	±10%	CON-35B
C-78	REC-30BF	150 μf	±10%	CON-35B
C-79	REC-30BF	150 μf	±10%	CON-35B
C-80	REC-30BF	150 μf	±10%	CON-35B
C-81	REC-30BF	150 μf	±10%	CON-35B
C-82	REC-30BF	150 μf	±10%	CON-35B
C-83	REC-30BF	150 μf	±10%	CON-35B
C-84	REC-30BF	150 μf	±10%	CON-35B
C-85	REC-30BF	150 μf	±10%	CON-35B
C-86	REC-30BF	150 μf	±10%	CON-35B
C-87	REC-30BF	150 μf	±10%	CON-35B
C-88	REC-30BF	150 μf	±10%	CON-35B
C-89	REC-30BF	150 μf	±10%	CON-35B
C-90	REC-30BF	150 μf	±10%	CON-35B
C-91	REC-30BF	150 μf	±10%	CON-35B
C-92	REC-30BF	150 μf	±10%	CON-35B
C-93	REC-30BF	150 μf	±10%	CON-35B
C-94	REC-30BF	150 μf	±10%	CON-35B
C-95	REC-30BF	150 μf	±10%	CON-35B
C-96	REC-30BF	150 μf	±10%	CON-35B
C-97	REC-30BF	150 μf	±10%	CON-35B
C-98	REC-30BF	150 μf	±10%	CON-35B
C-99	REC-30BF	150 μf	±10%	CON-35B
C-100	REC-30BF	150 μf	±10%	CON-35B
C-101	REC-30BF	150 μf	±10%	CON-35B
C-102	REC-30BF	150 μf	±10%	CON-35B
C-103	REC-30BF	150 μf	±10%	CON-35B
C-104	REC-30BF	150 μf	±10%	CON-35B
C-105	REC-30BF	150 μf	±10%	CON-35B
C-106	REC-30BF	150 μf	±10%	CON-35B
C-107	REC-30BF	150 μf	±10%	CON-35B
C-108	REC-30BF	150 μf	±10%	CON-35B
C-109	REC-30BF	150 μf	±10%	CON-35B
C-110	REC-30BF	150 μf	±10%	CON-35B
C-111	REC-30BF	150 μf	±10%	CON-35B
C-112	REC-30BF	150 μf	±10%	CON-35B
C-113	REC-30BF	150 μf	±10%	CON-35B
C-114	REC-30BF	150 μf	±10%	CON-35B
C-115	REC-30BF	150 μf	±10%	CON-35B
C-116	REC-30BF	150 μf	±10%	CON-35B
C-117	REC-30BF	150 μf	±10%	CON-35B
C-118	REC-30BF	150 μf	±10%	CON-35B
C-119	REC-30BF	150 μf	±10%	CON-35B
C-120	REC-30BF	150 μf	±10%	CON-35B
C-121	REC-30BF	150 μf	±10%	CON-35B
C-122	REC-30BF	150 μf	±10%	CON-35B
C-123	REC-30BF	150 μf	±10%	CON-35B
C-124	REC-30BF	150 μf	±10%	CON-35B
C-125	REC-30BF	150 μf	±10%	CON-35B
C-126	REC-30BF	150 μf	±10%	CON-35B
C-127	REC-30BF	150 μf	±10%	CON-35B
C-128	REC-30BF	150 μf	±10%	CON-35B
C-129	REC-30BF	150 μf	±10%	CON-35B
C-130	REC-30BF	150 μf	±10%	CON-35B
C-131	REC-30BF	150 μf	±10%	CON-35B
C-132	REC-30BF	150 μf	±10%	CON-35B
C-133	REC-30BF	150 μf	±10%	CON-35B
C-134	REC-30BF	150 μf	±10%	CON-35B
C-135	REC-30BF	150 μf	±10%	CON-35B
C-136	REC-30BF	150 μf	±10%	CON-35B
C-137	REC-30BF	150 μf	±10%	CON-35B
C-138	REC-30BF	150 μf	±10%	CON-35B
C-139	REC-30BF	150 μf	±10%	CON-35B
C-140	REC-30BF	150 μf	±10%	CON-35B
C-141	REC-30BF	150 μf	±10%	CON-35B
C-142	REC-30BF	150 μf	±10%	CON-35B
C-143	REC-30BF	150 μf	±10%	CON-35B
C-144	REC-30BF	150 μf	±10%	CON-35B
C-145	REC-30BF	150 μf	±10%	CON-35B
C-146	REC-30BF	150 μf	±10%	CON-35B
C-147	REC-30BF	150 μf	±10%	CON-35B
C-148	REC-30BF	150 μf	±10%	CON-35B
C-149	REC-30BF	150 μf	±10%	CON-35B
C-150	REC-30BF	150 μf	±10%	CON-35B
C-151	REC-30BF	150 μf	±10%	CON-35B
C-152	REC-30BF	150 μf	±10%	CON-35B
C-153	REC-30BF	150 μf	±10%	CON-35B
C-154	REC-30BF	150 μf	±10%	CON-35B
C-155	REC-30BF	150 μf	±10%	CON-35B
C-156	REC-30BF	150 μf	±10%	CON-35B
C-157	REC-30BF	150 μf	±10%	CON-35B
C-158	REC-30BF	150 μf	±10%	CON-35B
C-159	REC-30BF	150 μf	±10%	CON-35B
C-160	REC-30BF	150 μf	±10%	CON-35B
C-161	REC-30BF	150 μf	±10%	CON-35B
C-162	REC-30BF	150 μf	±10%	CON-35B
C-163	REC-30BF	150 μf	±10%	CON-35B
C-164	REC-30BF	150 μf	±10%	CON-35B
C-165	REC-30BF	150 μf	±10%	CON-35B
C-166	REC-30BF	150 μf	±10%	CON-35B
C-167	REC-30BF	150 μf	±10%	CON-35B
C-168	REC-30BF	150 μf	±10%	CON-35B
C-169	REC-30BF	150 μf	±10%	CON-35B
C-170	REC-30BF	150 μf	±10%	CON-35B
C-171	REC-30BF	150 μf	±10%	CON-35B
C-172	REC-30BF	150 μf	±10%	CON-35B
C-173	REC-30BF	150 μf	±10%	CON-35B
C-174	REC-30BF	150 μf	±10%	CON-35B
C-175	REC-30BF	150 μf	±10%	CON-35B
C-176	REC-30BF	150 μf	±10%	CON-35B
C-177	REC-30BF	150 μf	±10%	CON-35B
C-178	REC-30BF	150 μf	±10%	CON-35B
C-179	REC-30BF	150 μf	±10%	CON-35B
C-180	REC-30BF	150 μf	±10%	CON-35B
C-181	REC-30BF	150 μf	±10%	CON-35B
C-182	REC-30BF	150 μf	±10%	CON-35B
C-183	REC-30BF	150 μf	±10%	CON-35B
C-184	REC-30BF	150 μf	±10%	CON-35B
C-185	REC-30BF	150 μf	±10%	CON-35B
C-186	REC-30BF	150 μf	±10%	CON-35B
C-187	REC-30BF	150 μf	±10%	CON-35B
C-188	REC-30BF	150 μf	±10%	CON-35B
C-189	REC-30BF	150 μf	±10%	CON-35B
C-190	REC-30BF	150 μf	±10%	CON-35B
C-191	REC-30BF	150 μf	±10%	CON-35B
C-192	REC-30BF	150 μf	±10%	CON-35B
C-193	REC-30BF	150 μf	±10%	CON-35B
C-194	REC-30BF	150 μf	±10%	CON-35B
C-195	REC-30BF	150 μf	±10%	CON-35B
C-196	REC-30BF	150 μf	±10%	CON-35B
C-197	REC-30BF	150 μf	±10%	CON-35B
C-198	REC-30BF	150 μf	±10%	CON-35B
C-199	REC-30BF	150 μf	±10%	CON-35B
C-200	REC-30BF	150 μf	±10%	CON-35B
C-201	REC-30BF	150 μf	±10%	CON-35B
C-202	REC-30BF	150 μf	±10%	CON-35B
C-203	REC-30BF	150 μf	±10%	CON-35B
C-204	REC-30BF	150 μf	±10%	CON-35B
C-205	REC-30BF	150 μf	±10%	CON-35B
C-206	REC-30BF	150 μf	±10%	CON-35B
C-207</				

SPECIFICATIONS

Voltage at Unknown: The voltage applied to the unknown is 500 volts or 50 volts as selected by means of a panel switch. A neon lamp warns when the 500-volt supply has been selected. Over a 105-125-volt range in line voltage and over the resistance range of the instrument, the variation in voltage across the unknown resistor will be less than ± 10 volts at 500 volts and less than ± 4 volts at 50 volts.

Range: 0.5 megohm to 2,000,000 megohms at 500 volts and to 200,000 megohms at 50 volts. There are six decade steps as selected by a multiplier switch.

Scale: Each resistance decade up to 500,000 megohms (50,000 megohms for 50 volts) utilizes 90% of the meter scale. Center scale values are 1, 10, 100, 1000, and 10,000 megohms with, in addition, a center scale value of 100,000 megohms for 500-volt operation.

Accuracy: For 500-volt operation, the accuracy in percent of indicated value at all but the highest multiplier setting is $\pm 3\%$ at the low-resistance end of each decade, $\pm 8\%$ at mid-scale and $\pm 12\%$ at the high-resistance end. There can be an additional $\pm 2\%$ error at the highest multiplier setting. For 50-volt operation, there is an additional $\pm 2\%$ error on all but the 0.5-5 megohms decade where the additional error can be $\pm 5\%$.

Terminals: In addition to terminals for connecting the unknown, ground and guard terminals are provided. At two positions of the panel switch, all voltage is removed from all terminals to permit connection of the unknown in safety. In one of the positions, the UNKNOWN terminals are shunted to discharge the capacitive component of the unknown. All but the ground terminal are insulated.

Check: A switch position is provided for standardizing the calibration at 500 volts.

Design: Since field applications are more severe than laboratory use, the instrument was designed to be unusually rugged. The carrying case can be completely closed; accessory power cable and test leads are carried in the case. Controls are simplified for use by untrained personnel.

Tubes: Supplied with the instrument: one 12AU7, one OA2, one 6X4, one 2X2-A, one 6AB4, one 6AU6, one 5651 and one NE-51.

Controls: A switch for selecting the operating voltage, a switch for selecting the multiplying factor, a control for standardizing the calibration, a control for setting the meter to the infinity reading and a power switch.

Mounting: The instrument is assembled on an aluminum panel finished in black crackle lacquer and is mounted in an aluminum cabinet with black-wrinkle finish and with black-phenolic protective sides. The aluminum-cover finish is black wrinkle. The case is provided with a carrying handle.

Power Supply: 115 (or 230) volts at 40 to 60 cycles. The power input is about 25 watts.

Accessories Supplied: Two 3-foot color-coded test leads.

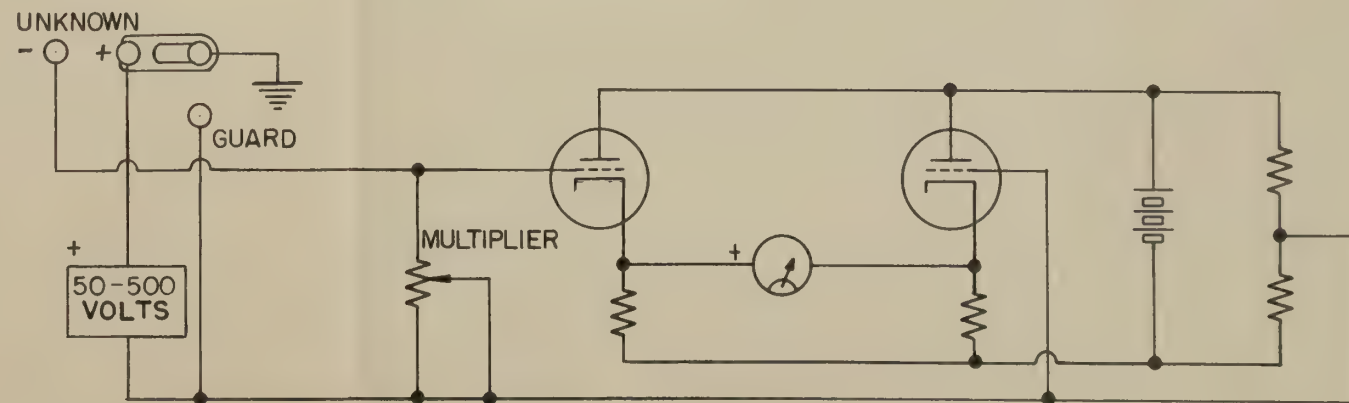
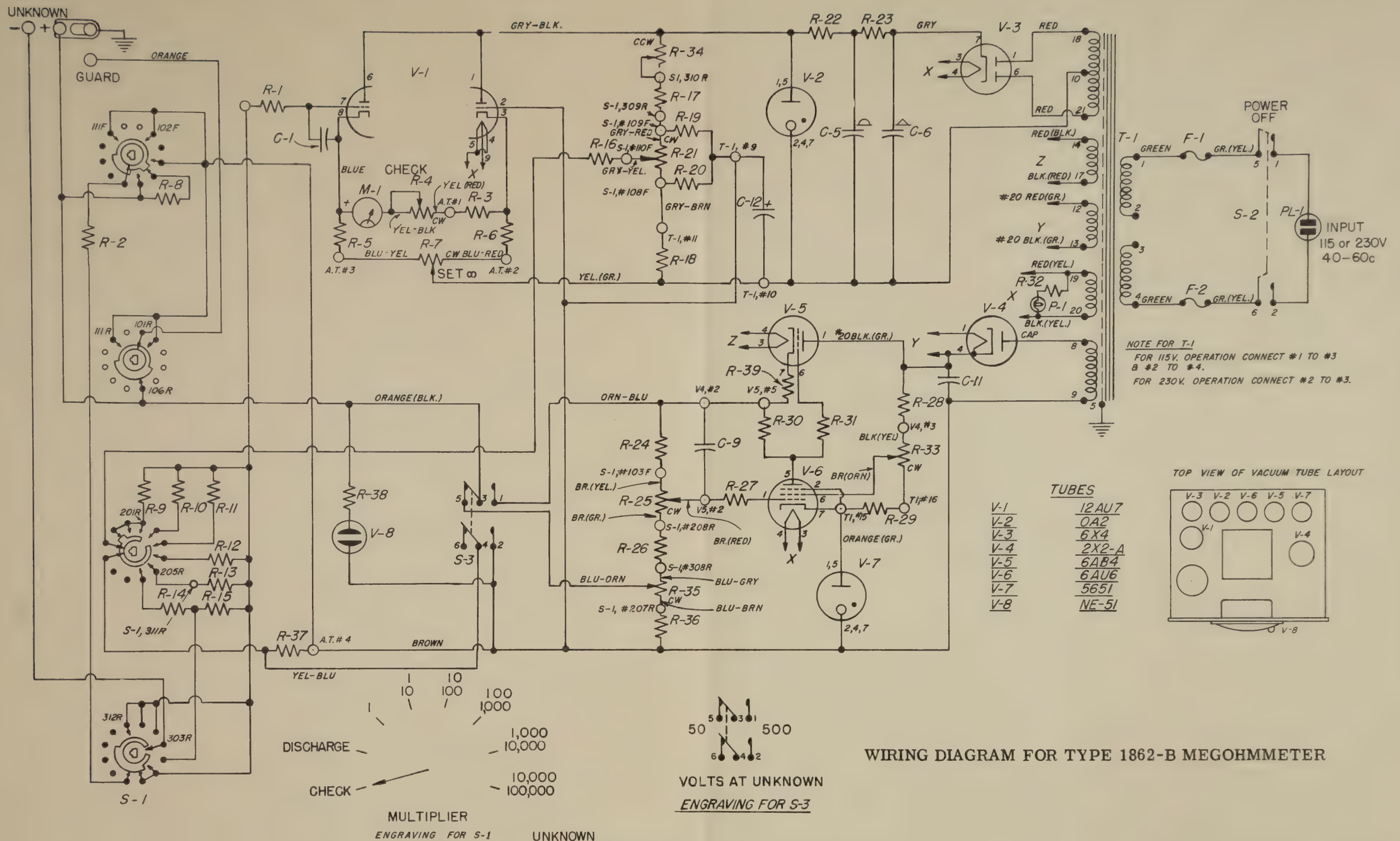
Dimensions: (Height) 10-1/8 inches x (width) 9-1/8 inches x (depth) 11-3/4 inches overall.

Weight: 15-1/4 pounds.

Parts List for Type 1862-B Megohmmeter

RESISTORS	TYPE	R-34 =	20 k Ohms	±10%	POSC-11
R-1 = 10 Megohms	REC-30BF	R-35 =	25 k Ohms	±10%	POSC-11
R-2 = 5.1 k Ohms	REW-6C	R-36 =	47 k Ohms	±5%	REC-30BF
R-3 = 4.3 k Ohms	REW-4C	R-37 =	620 Ohms	±5%	REC-30BF
R-4 = 3.3 k Ohms	POSW-3	R-38 =	2.2 Megohms	±10%	REC-30BF
R-5 = 100 k Ohms	REC-20BF	R-39 =	820 Ohms	±5%	REC-20BF
R-6 = 100 k Ohms	REC-20BF				
R-7 = 140 k Ohms	POSC-11				
R-8 = 495 k Ohms	REPR-17	C-1 =	.005 μ f	±10%	COM-35B
R-9 = 2 k Ohms	REPR-17	C-2			
R-10 = 20 k Ohms	REF-1-2	C-3			
R-11 = 200 k Ohms	REF-1-2	C-4			
R-12 = 2 Megohms	REF-1	C-5 =	20 μ f	450WV	COEB-20
R-13 = 20 Megohms	REF-80	C-6 =	20 μ f	450WV	
R-14 = 100 Megohms	REF-80	C-7			
R-15 = 100 Megohms	REF-80	C-8			
R-16 = 1 Megohm	REC-20BF	C-9 =	.15 μ f	±10%	COL-57
R-17 = 15 k Ohms	REC-20BF	C-10			
R-18 = 62 k Ohms	REC-20BF	C-11 =	.25 μ f	±10%	COL-26
R-19 = 22 k Ohms	REC-20BF	C-12 =	16 μ f	150 WV	COE-4
R-20 = 22 k Ohms	REC-20BF				
R-21 = 500 Ohms	POSW-3	MISCELLANEOUS			
R-22 = 330 Ohms	REC-20BF	S-1 =	Switch	4P8T	SWRW-63
R-23 = 5.1 k Ohms	REW-6C	S-2 =	Switch	DPST	SWT-333
R-24 = 560 k Ohms	REC-30BF	S-3 =	Switch	DPDT	SWT-335
R-25 = 20 k Ohms	POSC-11	M-1 =	Meter	200 μ a	MEDS-104
R-26 = 24 k Ohms	REC-20BF				
R-27 = 1 Megohm	REC-20BF	F-1, F-2 =	0.4 amp for 115V Slo-Blo 3AG	GR FUF-1	
R-28 = 270 k Ohms	REC-41BF	F-1, F-2 =	0.2 amp for 230V Slo-Blo 3AG	GR FUF-1	
R-29 = 22 k Ohms	REC-20BF				
R-30 = 100 k Ohms	REC-20BF	P-1 =	Pilot Light	2LAP-939	
R-31 = 100 k Ohms	REC-20BF	PL-1 =	Plug	CAP-1-2	
R-32 = 15 Ohms	REW-3C *	T-1 =	Transformer		485-468-2
R-33 = 100 k Ohms	POSC-11				

*Part of P-1 Socket



GENERAL RADIO COMPANY

WEST CONCORD, MASSACHUSETTS

EMerson 9-4400

Clearwater 9-8900

DISTRICT OFFICES

NEW YORK

Broad Ave. at Linden, Ridgefield, N. J.
Telephone N.Y. WOrth 4-2722
N.J. WHitney 3-3140

PHILADELPHIA

1150 York Rd., Abington, Penna.
Telephone HANcock 4-7419

WASHINGTON

8055 13th St., Silver Spring, Md.
Telephone JUniper 5-1088

CHICAGO

6605 West North Ave., Oak Park, Ill.
Telephone VIlage 8-9400

LOS ANGELES

1000 N. Seward St., Los Angeles 38,
Calif.
Telephone HOLlywood 9-6201

SAN FRANCISCO

1186 Los Altos Ave., Los Altos, Calif.
Telephone WHitecliff 8-8233

CANADA

99 Floral Pkwy., Toronto 15, Ont.
Telephone CHerry 6-2171

REPAIR SERVICES

EAST COAST

General Radio Company
Service Department
22 Baker Ave., W. Concord, Mass.
Telephone EMerson 9-4400

NEW YORK

General Radio Company
Service Department
Broad Ave. at Linden, Ridgefield, N. J.
Telephone N.Y. WOrth 4-2722
N.J. WHitney 3-3140

MIDWEST

General Radio Company
Service Department
6605 West North Ave., Oak Park, Ill.
Telephone VIlage 8-9400

WEST COAST

Western Instrument Co.
826 N. Victory Blvd., Burbank, Calif.
Telephone VICTORIA 9-3013

CANADA

Bayly Engineering, Ltd.
First Street, Ajax, Ontario
Telephone Toronto EMpire 8-6866

— INSTRUCTION MANUAL —

MODEL NO: 1521-A

FUNCTION: GRAPHIC LEVEL RECORDER

ORIGINAL MANUFACTURER: GENERAL RADIO CO.

**Type 1390-B
Random-Noise
Generator**

N

© GENERAL RADIO COMPANY 1972

Concord, Massachusetts, U.S.A. 01742

Form 1390-0100-N

October, 1972

ID-4627

SPECIFICATIONS

Frequency Range: 5 c/s to 5 Mc/s.

Output Voltage: Maximum open-circuit output is at least 3 V for 20-kc range, 2 V for 500-kc range, and 1 V for 5-Mc range.

Output Impedance: Source impedance for maximum output is approximately 900 Ω . Output is taken from a 2500- Ω potentiometer. Source impedance for attenuated output is 200 Ω . One output terminal is grounded.

Typical Spectrum Level		Spectrum Level Uniformity*
Range	(with 1-V, rms, output)	
20 kc/s	5 mV for 1-cycle band	within ± 1 dB, 20 c/s to 20 kc/s
500 kc/s	1.2 mV for 1-cycle band	within ± 3 dB, 20 c/s to 500 kc/s
5 Mc/s	0.6 mV for 1-cycle band	within ± 3 dB, 20 c/s to 500 kc/s; within ± 8 dB, 500 kc/s to 5 Mc/s

*Noise energy also present beyond these limits. Level is down 3 dB at 5 c/s. See plot.

Waveform: Noise source has good normal, or Gaussian, distribution of amplitudes for ranges of the frequency spectrum that are

narrow compared to the band selected. Over wide ranges the distribution is less symmetrical because of dissymmetry introduced by the gas tube. Some clipping occurs on the 500-kc and 5-Mc ranges.

Voltmeter: Rectifier-type averaging meter measures output. It is calibrated to read rms value of noise.

Attenuator: Multiplying factors of 1.0, 0.1, 0.01, 0.001, and 0.0001. Accurate to $\pm 3\%$ to 100 kc/s, within $\pm 10\%$ to 5 Mc/s.

Power Required: 105 to 125 or 210 to 250 V, 50 to 400 c/s, 50 W.

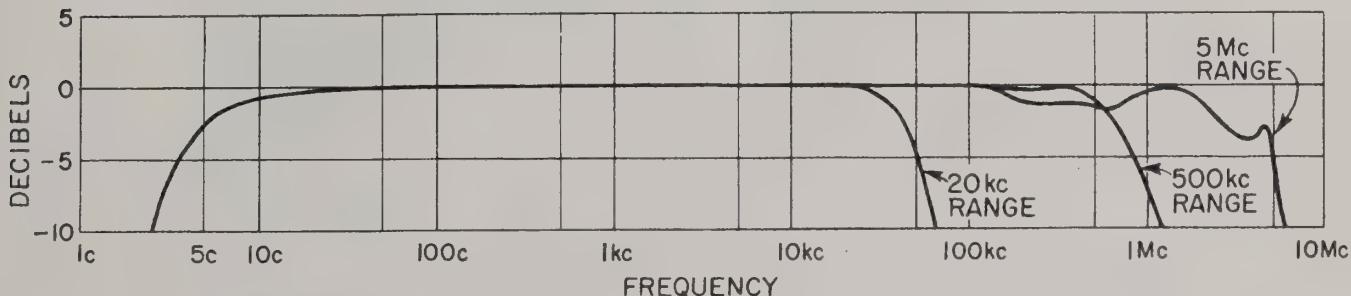
Accessories Supplied: TYPE CAP-22 Power Cord, spare fuses.

Accessories Available: Rack-adaptor panel (panel height 7 in).

Mechanical Data: Convertible-Bench Cabinet

Width		Height		Depth		Net Weight		Shipping Weight	
in	mm	in	mm	in	mm	lb	kg	lb	kg
12¾	325	7½	190	9¾	250	12	5.5	16	7.5

For additional information, ask for General Radio Reprint E-110.



WARRANTY

We warrant that this product is free from defects in material and workmanship and, properly used, will perform in full accordance with applicable specifications. If, within a period of ten years after original shipment, it is found, after examination by us or our authorized representative, not to meet this standard, it will be repaired or, at our option, replaced as follows:

- No charge for parts, labor or transportation during the first three months after original shipment;
- No charge for parts or labor during the fourth through the twelfth month after original shipment for a product returned to a GR service facility;
- No charge for parts during the second year after original shipment for a product returned to a GR service facility;

- During the third through the tenth year after original shipment, and as long thereafter as parts are available, we will maintain our repair capability and it will be available at our then prevailing schedule of charges for a product returned to a GR service facility.

This warranty shall not apply to any product or part thereof which has been subject to accident, negligence, alteration, abuse or misuse; nor to any parts or components that have given normal service. This warranty is expressly in lieu of and excludes all other warranties expressed or implied, including the warranties of merchantability and fitness for a particular purpose, and all other obligations or liabilities on our part, including liability for consequential damages resulting from product failure or other causes. No person, firm or corporation is authorized to assume for us any other liability in connection with the sale of any product.

TABLE OF CONTENTS

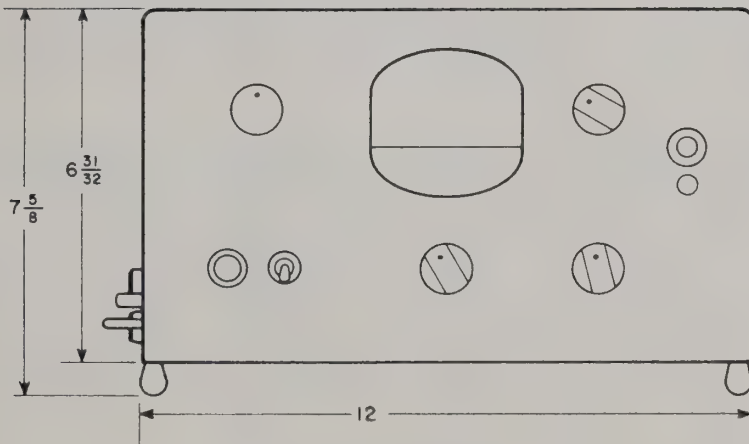
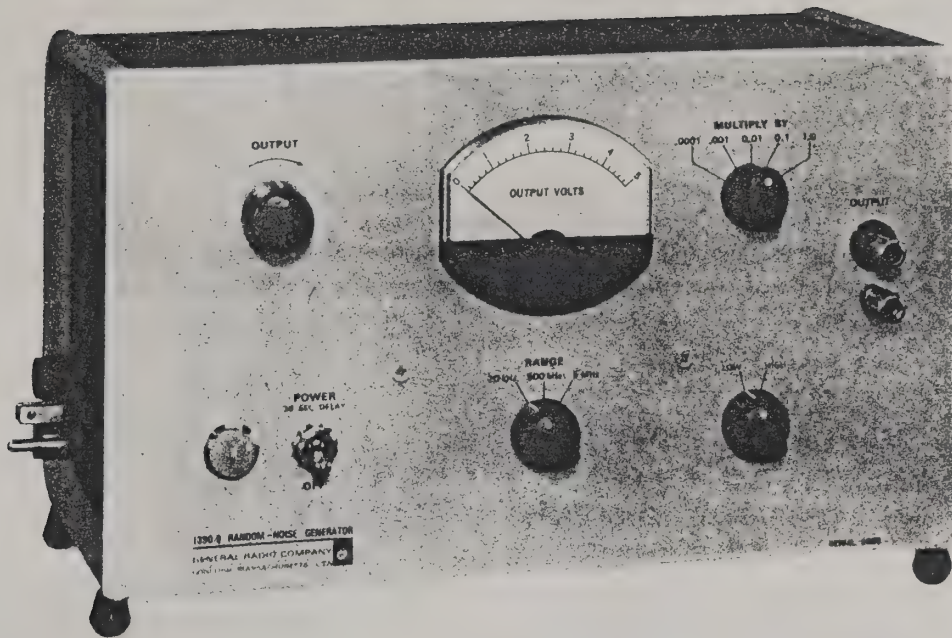
Section 1 INTRODUCTION	1
1.1 Purpose	1
1.2 Description	1
Section 2 THEORY OF OPERATION	2
2.1 General	2
2.2 Output Voltage	2
2.3 Characteristics of Noise Output	2
2.4 Departures of Output from True Randomness	4
2.5 Frequency Spectrum of Noise	4
2.6 Analysis of Noise by Constant-Percentage Analyzers	4
2.7 Type 1390-P2 Pink-Noise Filter	4
Section 3 INSTALLATION	6
3.1 Bench Mounting	6
3.2 Relay-Rack Mounting	6
3.3 Power Supply Connection	6
Section 4 OPERATING PROCEDURE	6
4.1 Start-Up	6
4.2 Frequency Control	6
4.3 Output Control	6
4.4 Voltmeter	6
4.5 Load	7
4.6 Hum	7
4.7 Applications	7
Section 5 SERVICE AND MAINTENANCE	11
5.1 Service	11
5.2 Minimum-Performance Standards	11
5.3 Access to Components	11
5.4 Preliminary Checks	11
5.5 Tube Replacement	11
5.6 Heater Voltage of Type 6D4 Gas Tube	11
5.7 Voltage Measurements	12
5.8 Voltmeter Calibration	12
PARTS LIST	13

Handbook of Noise Measurement

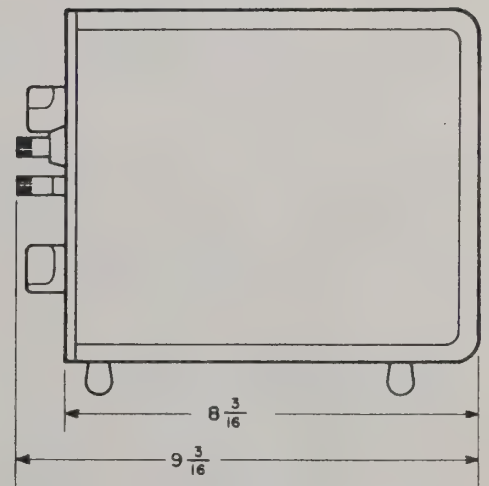
This 320-page book, by Dr. A. P. G. Peterson and Ervin E. Gross, Jr., of the General Radio Engineering Staff covers thoroughly the subject of noise and vibration measurement. Copies are available from General Radio at \$7.50 each, postpaid in the United States and Canada.

NOTE

Hz (hertz) = cps



DIMENSIONS IN INCHES



1390-1

Figure 1. Type 1390-B Random-Noise Generator. (See Section 3 for different mounting arrangements).

Section 1

INTRODUCTION

1.1 PURPOSE. The Type 1390-B Random-Noise Generator (Figure 1) provides a high level of electrical noise at its output terminals. This type of signal is useful in room acoustic measurements, loudspeaker and microphone tests, psychoacoustic tests, filter tests, cross-talk measurements for multichannel carrier systems, calibration checks on recording systems, modulation of signal generators and test oscillators, tests of rms response of meters, observation of resonance in systems, electrical averaging of resonant responses, and comparisons of effective band width. A pair of these genera-

tors can be used as signal sources for demonstration of various degrees of correlation, possible errors of random sampling, and other concepts of statistical theory.

1.2 DESCRIPTION.

1.2.1 CONNECTIONS. Two jack-top binding posts, used as output terminals, are provided on the panel of the Type 1390-B Random-Noise Generator.

1.2.2 CONTROLS. The following controls are on the panel of the Type 1390-B Random-Noise Generator:

Name	Description	Positions	Use
RANGE	3-position rotary selector switch	20 kc, 500 kc, 5 Mc	Selects network used for shaping noise spectrum
POWER	2-position toggle switch	OFF, POWER	Energizes instrument.
None	2-position rotary selector switch	LOW, HIGH	In LOW position, introduces a 10:1 resistance pad after gas-tube noise source to reduce effect of amplitude limitations of amplifier and to reduce noise field radiated by the instrument.
OUTPUT	Continuous rotary control		Varies output voltage.
OUTPUT VOLTS	Rectifier-type, averaging voltmeter		Indicates rms value of noise at output terminals.
MULTIPLY BY	5-position rotary selector switch	0.0001, 0.001, 0.01, 0.1, 1.0	Attenuates output voltage.

Section 2

THEORY OF OPERATION

2.1 GENERAL. (See Figure 2.) The Type 1390-B Random-Noise Generator uses a gas-discharge tube as its noise source. A transverse magnetic field is applied to the tube to eliminate the oscillations usually associated with a gas discharge and to increase the noise level at high frequencies¹. The noise output from the gas tube is amplified in a two-stage amplifier. Between the first and second stages the noise spectrum is shaped in one of three different ways, depending on the setting of the RANGE switch. At the 20-kc position, a low-pass filter is inserted, which has a gradual roll-off above 30 kc, with the audio range to 20 kc uniform in spectrum level. At the 500-kc setting, a low-pass filter is inserted, which rolls off above 500 kc. At the 5-Mc setting, a peaking network is used. This network approximately compensates for the drop in noise output from the gas tube at high frequencies, so that a reasonably good spectrum is obtainable to 5 Mc.

2.2 OUTPUT VOLTAGE. The maximum open-circuit output voltage on the 20-kc band is at least 3 volts, on the 500-kc band at least 2 volts, and on the 5-Mc band at least 1 volt. This corresponds to a relatively high noise level, since the output impedance at maximum output is only about 900 ohms. This level can be expressed in terms of the resistance noise corresponding to 900 ohms at room temperature. The rms voltage in a one-cycle band due to thermal agitation in a 900-ohm resistor at room temperature is about 3.8×10^{-9} volt. The level from the Type 1390-B Random-Noise Generator is about five millivolts for a one-cycle band when there is a total output voltage of one volt on the 20-kc band. This level, then, is about 1,300,000 times the corresponding voltage for resistance noise,

or about 122 decibels above resistance noise at the same impedance level.

2.3 CHARACTERISTICS OF NOISE OUTPUT. As shown in Figure 3, no regular pattern appears in the output waveform; it is characterized by randomness rather than by regularity. Noise is therefore described by statistical means,² and is characterized by its distribution of instantaneous amplitudes and by its frequency spectrum.

A random noise is often defined as a noise that has a "normal" or "Gaussian" distribution of amplitudes. This concept is illustrated by the following simple experiment performed with the noise generator.

Set the noise generator to the 20-kc band and to maximum output. Connect a small capacitor (about 1000 pf) across the output. Suddenly disconnect the capacitor. Measure its voltage with an electrometer or

¹ J. D. Cobine and J. R. Curry, "Electrical Noise Generators", *Proc. IRE*, Vol. 35, No. 9, September 1947, pp. 875-879.

² S. O. Rice, "Mathematical Analysis of Random Noise", *Bell System Technical Journal*, Vol. 23, No. 3, July 1944, pp. 282-332; Vol. 24, No. 1, January 1945, pp. 46-156.

A. van der Ziel, *Noise*, New York, Prentice-Hall, Inc., 1954.

W. B. Davenport, Jr. and W. L. Root, *An Introduction to the Theory of Random Signals and Noise*, New York, McGraw-Hill, 1958.

W. R. Bennett, *Electrical Noise*, New York, McGraw-Hill, 1960.

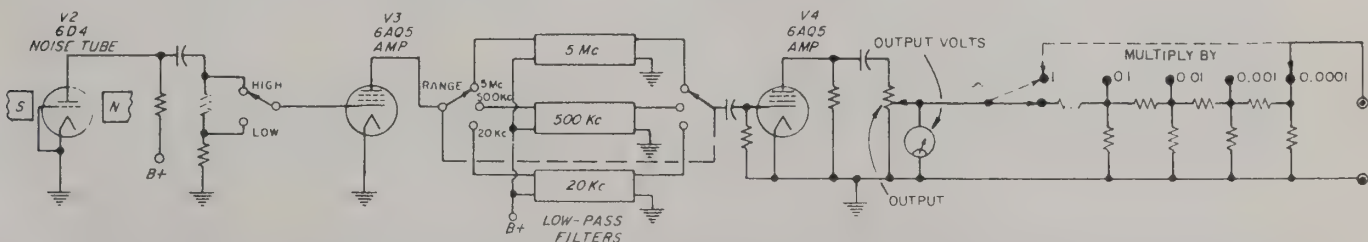


Figure 2. Elementary Circuit Diagram.

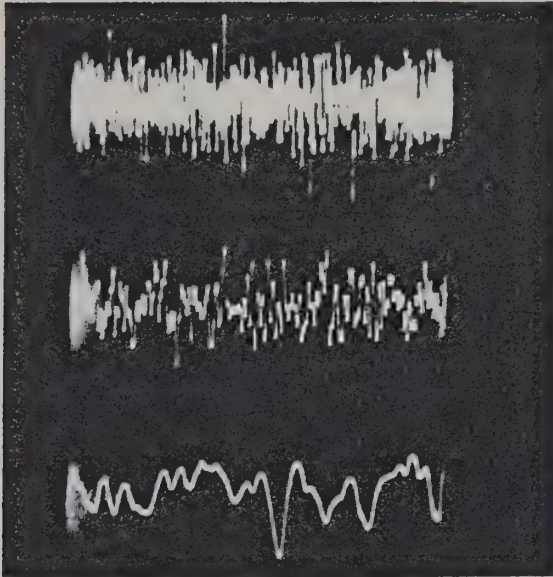


Figure 3. Oscillograms of Three Different Samples of the Output Voltage Wave. (A single sweep was used for each. Middle trace is at four times, and lower trace 20 times sweep speed of upper trace.)

its charge with a ballistic galvanometer. Record this value, which is the instantaneous amplitude of the noise voltage at the time the capacitor is disconnected. A series of these values can be obtained, and a graph prepared, with instantaneous amplitude versus the percentage of time during which any amplitude is exceeded. A large number of amplitudes must be determined in this way before a reliable distribution results. Two or three hundred observations are usually sufficient to show the trend for demonstration purposes, while several thousand will give a reliable curve for the important part of the range. Because of the large number of observations required, automatic apparatus is helpful in making these determinations.³

Figure 4 illustrates a chart made up after 400 observations. This chart shows the fraction of observations in each interval of 0.2 volt. It is seen that most of the observations were relatively low values, although some relatively high values were observed. These results are also shown in a qualitative way in the oscillograms in Figure 3.

³ McKnudson, "Experimental Study of Statistical Characteristics of Filtered Random Noise", Technical Report No. 115, M.I.T. Research Laboratory of Electronics, July 15, 1949.

L. W. Orr, "Wide-Band Amplitude Distribution Analysis of Voltage Sources", *Review of Scientific Instruments*, Vol. 25, No. 9, Sept., 1954, pp. 894-898.

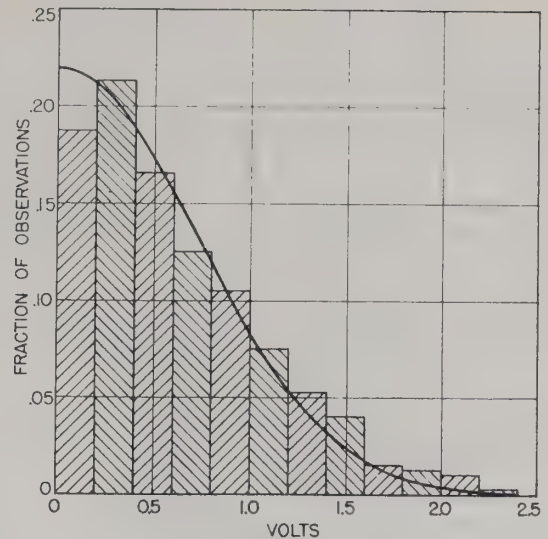


Figure 4. Results of Voltage-Sampling Experiment. (Continuous curve is a normal probability distribution curve adjusted according to r-m-s value of noise voltage and size of intervals used in plot.)

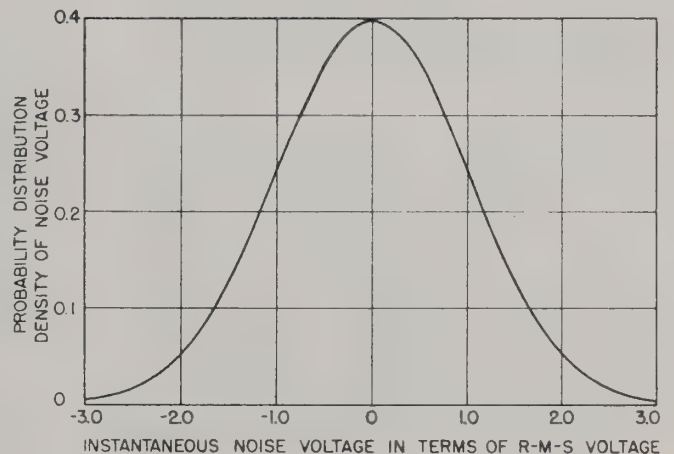


Figure 5.

Normal Distribution Curve of True Random Noise.

The normal (Gaussian or Laplacian) distribution curve is also shown in Figure 4. It has been adjusted according to the computed r-m-s value of the data (the standard deviation) and the size of the interval used in plotting the data. The experimental data fit the normal curve very closely. Departures from the normal curve are almost entirely the result of so few observations. Had more observations been made, the result would have been even closer to the expected values.³

In Figure 5, the probability that a voltage between two limits will be observed is given by the area under the normal curve between those two limits. Ex-

pressed in other terms, if the output voltage is observed over long periods of time, the fraction of the total time that the voltage is between the two voltage limits is given by the corresponding area under the probability curve.⁴ For example, the instantaneous voltage magnitude will be no more than one-tenth the r-m-s value for about eight percent of the time, and will be greater than three times the rms value only about 0.26 percent of the time.

2.4 DEPARTURES OF OUTPUT FROM TRUE RANDOMNESS. The curve in Figure 5 is a theoretical curve and is symmetrical about the origin. The noise of the generator has a similar distribution, but is somewhat asymmetrical because of the gas tube. In addition, the inherent amplitude limitations of the vacuum-tube amplifiers limit the distribution curve at high levels. Clipping is most serious on the 500-kc and 5-Mc ranges. When a narrow-band filter is used at the output, the distribution becomes more nearly random.

2.5 FREQUENCY SPECTRUM OF NOISE. The meaning of the term "frequency spectrum of noise" is illustrated in the following experiment. If a wave analyzer, such as the Type 1900-A, set to a 50-cps bandwidth, is used to analyze the output of the noise generator, a fluctuating meter reading will be observed at any setting of the analyzer. If an average value of this reading is taken over a period of time, this average value is an estimate of the level in that 50-cycle-wide band. This level, determined on any ranges of the noise generator, is essentially independent of the frequency setting of the Type 1900-A Wave Analyzer. Thus the spectrum in this region is uniform. The relative spectrum on the noise can be determined by the use of suitable analyzers to cover the full range of the principal energy regions of the noise. A typical result of such an analysis is shown in Figure 6 for the three bands of the Type 1390-B Random Noise Generator. When the spectrum is uniform over a broad band, as shown in Figure 6, it is commonly called "white noise". The "whiteness" always applies to a definite band only. For example, if the noise spectrum is uniform from 100 to 500 kc, the noise is referred to as white in that band.

It is customary to adjust the measured value of analyzed noise to that corresponding to an ideal filter of one-cycle band width. Since noise voltage increases as the square root of the band width, the value determined on the Type 1900-A Wave Analyzer is then divided by $\sqrt{\frac{50 \text{ cycles}}{1 \text{ cycle}}}$ to obtain what is called "spectral voltage density". This can be defined as the

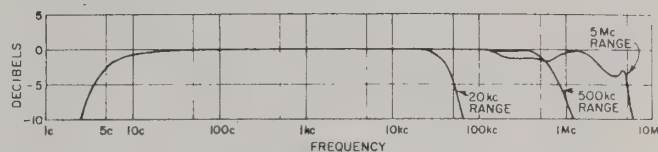


Figure 6. Typical Spectrum Level Characteristics for Type 1390-B Random-Noise Generator.

rms voltage corresponding to the energy contained within a band one cycle per second wide.

NOTE

"Spectral voltage density", although a convenient term, is sometimes not used because most work on noise deals with energy level. The transfer from one to the other requires a knowledge of the impedance level in the circuit. It should be remembered that separate noise signals add on an energy basis and that the noise energy increases directly with the noise bandwidth, while the noise voltage increases as the square root of the bandwidth. Furthermore, the concept used here assumes a uniform density of the noise signal over the band of the analyzer. It should not be used for discrete components.

2.6 ANALYSIS OF NOISE BY CONSTANT-PERCENTAGE ANALYZERS. If the output of the Type 1390-B Random-Noise Generator is analyzed by a Type 1564-A Sound and Vibration Analyzer, the results will be similar to those shown in Figure 7. Here the indicated level increases 10 decibels for each decade increase in frequency. This result can be understood by realizing that this analyzer has a bandwidth that is essentially a constant percentage of the center frequency. For example, at 5 kc the effective band width for noise is about 160 cps, and at 500 cps is about 16 cps.

2.7 TYPE 1390-P2 PINK-NOISE FILTER.

2.7.1 DESCRIPTION. The Type 1390-P2 Pink-Noise Filter (Figure 8) converts the electrical noise output

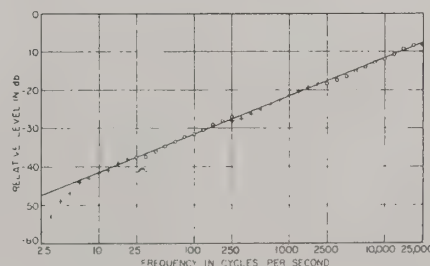


Figure 7. Results of Analysis of Noise-Generator Output Voltage by a Type 1564-A Analyzer. (Straight line drawn at slope of 10 db per frequency decade.)

⁴ E. R. Neinburg and T. F. Rogers, "Amplitude Distribution Analyzer", *Radio-Electronic Engineering*, Vol. 46, No. 6, December 1951, pp. 8-10.

TYPE 1390-B RANDOM-NOISE GENERATOR

of the Type 1390-B Random-Noise Generator to "pink noise" (constant energy per octave) which facilitates measurements with constant-percentage-bandwidth analyzers. It is designed to plug into the output binding posts of the Type 1390-B Random-Noise Generator, but can also be used at any point in a system where this filter characteristic is needed. The filter is an RC low-pass filter with a slope of -3 db per octave from 20 cycles to 20 kc and a slope of -6 db at higher frequencies (See Figure 9). For shielding, the case of the filter is grounded to the LO input and output terminals. Figure 10 is a schematic diagram of the filter. The input terminals of the Type 1390-P2 Filter are recessed plugs at the rear and the output terminals are binding posts on the front.

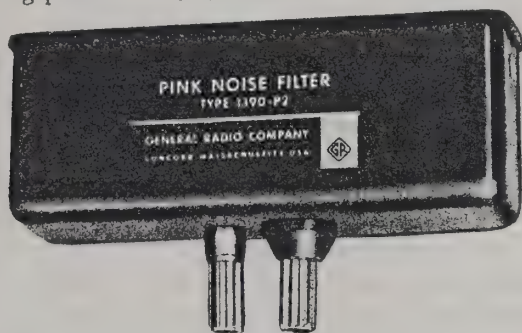


Figure 8. Type 1390-P2 Pink-Noise Filter.

2.7.2 USE WITH THE TYPE 1390-B RANDOM-NOISE GENERATOR. Plug the Type 1390-P2 Pink-Noise Filter into the output terminals of the Type 1390-B Random-Noise Generator. The impedance of the load connected to the output terminals of the filter should not be less than 20 kilohms.

On the Random-Noise Generator, set the RANGE switch to 20 kc, the LOW-HIGH switch to HIGH, and the MULTIPLY BY switch to 1.0. The output of the Pink-Noise Filter will be approximately 30 db below its input and the level in each one-third-octave band will be approximately 17 db below that. Thus, when the output meter of the Random-Noise Generator indicates 3 volts, the output of the filter will be approximately 0.1 volt and the level in each one-third-octave band will be approximately 15 millivolts.

2.7.3 USE IN OTHER APPLICATIONS. When the Type 1390-P2 Pink-Noise Filter is used in a system at some point other than the output terminals of the Random-Noise Generator, the input source to the filter should have an impedance of less than 1 kilohm. Input connections can be made with clip leads or Type 274-MB Double Plugs to the recessed input terminals. The impedance of the load connected to the output terminals should not be less than 20 kilohms.

2.7.4 FREQUENCY-RESPONSE MEASUREMENTS. In many acoustical systems, frequency response measurements made with a sine-wave tone source are difficult to interpret because of the large amplitude fluctuations

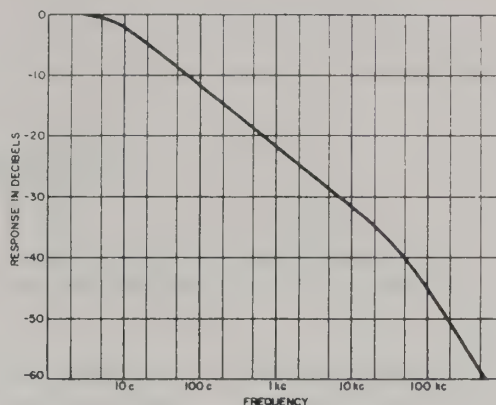


Figure 9. Typical frequency response of the Type 1390-P2 Pink-Noise Filter.

that may occur. When the measurements are made by effectively averaging the data over a narrow range of frequencies, response curve is considerably smoother and much easier to use. In the past, "warble tones" have been used for this purpose. A more convenient method, however, is to use pink-noise as the tone source and a constant-percentage-bandwidth analyzer (such as the Type 1564-A Sound and Vibration Analyzer) with one-third octave bandwidth as the frequency-determining element in the receiving system.⁵ The results of these frequency-response measurements can be conveniently recorded on the Type 1521 Graphic Level Recorder.⁶

2.7.5 USE AS A NOISE SIMULATOR. Some noises that occur in nature are closer in spectral characteristics to pink noise than to white noise. This is true, for instance, of the low-frequency noise in semiconductors and of some acoustical background noises. To simulate electrical signals generated in such cases, it is convenient to use pink noise.

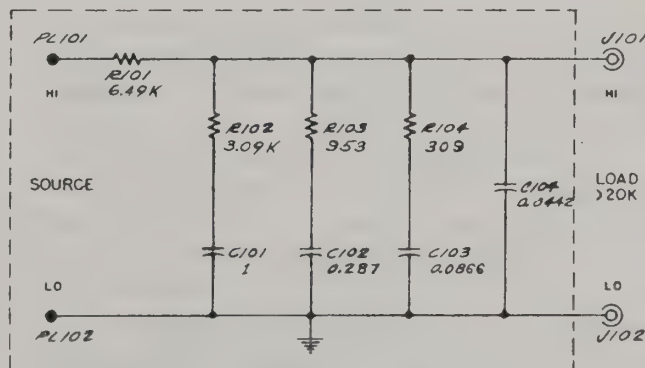


Figure 10. Schematic diagram of the Pink-Noise Filter.

⁵"A New Analyzer for Sound and Vibration", *General Radio Experimenter*, Volume 33, Number 12, December, 1959.

⁶"A Graphic Level Recorder with High Sensitivity and Wide Ranges", *General Radio Experimenter*, Volume 33, Number 6, June, 1959.

Section 3

INSTALLATION

3.1 BENCH MOUNTING. To set the instrument in a tilted position (shown in inset of Figure 1), simply pull each front leg down as far as possible and then turn the leg so that its notch faces the back of the instrument.

To restore the leg to its retracted position, turn it to release the catch and push the leg up.

3.2 RELAY-RACK MOUNTING. Type 480-P412 Panel Extensions are available to adapt the Type 1390-B Random-Noise Generator for relay-rack mounting. To mount the Type 1390-B Random-Noise Generator in a relay rack, first attach the two panel extensions to the instrument. Remove the two screws in the upper and lower corners on one side of the panel. These screws fasten the panel to the aluminum end frames. Place one of the extensions in the front of the panel so that the corner holes on the plate line up with those on the instrument and replace the two screws.

Attach the second extension on the other side of

the instrument panel in the same manner. The instrument can then be mounted in a standard 19-inch relay rack.

3.3 CONNECTION TO POWER SUPPLY. Connect the Type 1390-B to a source of power as indicated by the legend at the input socket at the rear of the instrument, using the power cord provided. While instruments are normally supplied for 115-volt operation, the power transformer can be reconnected for 230-volt service (see schematic diagram, Figure 12). When changing connections, be sure to replace line fuses with those of current rating for the new input voltage (refer to Parts List). Appropriate measures should be taken so that the legend indicates the new input voltage. On instruments changed from 230 to 115 volts, this simply means removal of the 230-v nameplate; a 115-v legend is marked beneath. For instruments changed to 230 volts, a nameplate (Type 5590-1664) may be ordered from General Radio.

Section 4

OPERATING PROCEDURE

4.1 START-UP. Turn the POWER switch on. After 30 seconds, when the heater of the Type 6D4 thyratron tube has warmed up, plate voltage is applied by an internal time-delay relay. (Simultaneous application of heater and plate voltage would shorten the useful life of the thyratron tube and increase the drift in noise-output level on warm-up.)

4.2 FREQUENCY CONTROL. The RANGE switch selects the network used for shaping the noise spectrum. Markings indicate the upper frequency limits for which the noise spectrum is reasonably uniform.

4.3 OUTPUT CONTROL. Output controls are a switch for selecting LOW or HIGH output, an OUTPUT level control, and an output attenuator. In the LOW position, the switch introduces a 10:1 resistance pad after the gas-tube noise source. This reduces the effect of the

unavoidable amplitude limitations of the vacuum-tube amplifier and also reduces the noise field radiated externally by the instrument. To keep hum and microphonics to a minimum, however, it is generally advisable to operate the instrument in the HIGH position.

The OUTPUT level control is a continuous-type control that is used to vary the output voltage from a very low value to maximum for either setting of the output switch.

The MULTIPLY BY switch is used to provide low output levels. It has multiplying factors of 1.0, 0.1, 0.01, 0.001, and 0.0001.

4.4 VOLTMETER. A rectifier-type, averaging meter measures the output voltage. It is calibrated to indicate the rms value of the noise. When the MULTIPLY BY switch is at 1.0, the meter indicates directly the open-circuit voltage at the output terminals. In the other positions of the MULTIPLY BY switch, the open-

circuit output voltage is the product of the meter reading and the multiplier reading.

The spectral voltage density of the noise at a given frequency is the r-m-s voltage corresponding to the energy contained within a band 1-cps wide centered on that frequency. The typical spectral voltage density at 1 kc with one volt output is approximately as follows:

- (a) 20-kc band: 5 millivolts for one-cycle band.
- (b) 500-kc band: 1.2 millivolts for one-cycle band.
- (c) 5-Mc band: 0.6 millivolt for one-cycle band.

When an accurate value is desired at any frequency, it should be measured. The values given are intended only as a guide.

4.5 LOAD. The output is taken from a 2500-ohm potentiometer, and one output terminal is grounded. For a truly resistive load with the MULTIPLY BY switch at 1.0, the apparent source impedance is zero when a reading of the voltmeter is taken with the load connected, since the voltmeter reads the voltage across the load. As the output control is varied from the maximum to the minimum setting, the actual source impedance varies from about 900 ohms to nearly zero. When the MULTIPLY BY switch is in any position other than 1.0, the source impedance is 200 ohms.

A load that is not independent of frequency will affect the frequency spectrum of the output noise. For example, a capacitor shunted across the output terminals will decrease the level of the high-frequency noise more than it decreases the level of the noise at low frequencies. The voltmeter is then less indicative of the spectrum level than it is for a resistive load.

4.6 HUM. The hum level is usually more than 40 db below the over-all noise level in the HIGH output position. This hum level is sufficiently low so that for most applications there is no effect from hum, even when an analyzer with a narrow band is used for analysis. The relative hum level in the HIGH output position is lower than that in the LOW position.

4.7 APPLICATIONS.

4.7.1 GENERAL. Some applications of a noise generator depend on its amplitude distribution characteristics (Figures 4 and 5.) For example, the amplitude distribution is similar to that of speech, music, and many other sounds or electrical disturbances that occur naturally⁷, while the amplitude distribution of a sine

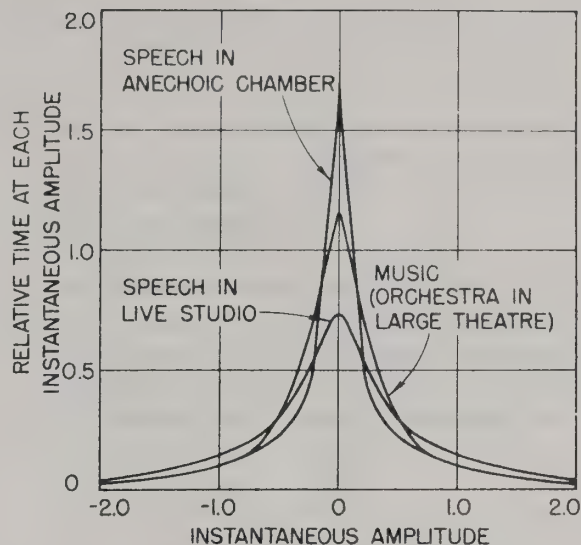


Figure 11a. Amplitude Distribution Curves for Various Sounds. (Curves labeled "Speech" are for particular cases of sounds produced from readings of printed matter⁵; curve labeled "Music" is an analysis of an orchestral selection made in a large theater⁵.)

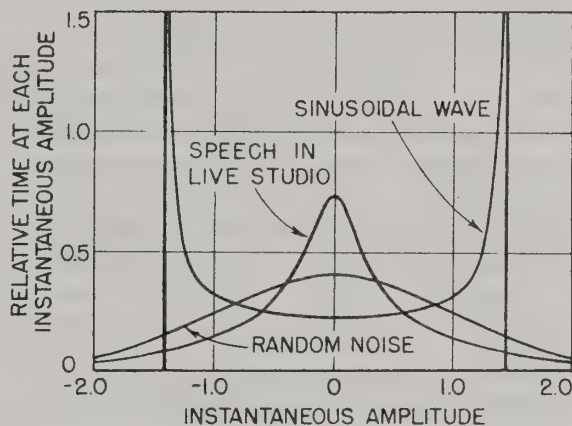


Figure 11b. Distribution Curves of a Single Sinusoidal Wave and a Random Noise.

wave is entirely different. These similarities and differences can be seen by comparison of the distributions of Figure 11. Because of this characteristic, random noise is an important signal for psychoacoustic tests. Psychoacoustic tests include masking or interference tests, loudness measurements, determination of critical bandwidths, and audiometric tests. The techniques used in making such tests are discussed in the various numbers of the *Journal of the Acoustical Society*

⁷ H. K. Dunn and S. D. White, "Statistical Measurements on Conversational Speech", *Journal of the Acoustical Society of America*, Vol. 11, No. 3, January 1940, pp. 278-288.

W. B. Davenport, Jr. "A Study of Speech Probability Distributions", *M.I.T. Laboratory of Electronics, Technical Report No. 148*, August 25, 1950.

of America (for which there are two comprehensive indexes available) and in various psychological journals. A useful bibliography for these applications is S. S. Stevens, J. G. S. Loring, and Dorothy Cohen, Bibliography on Hearing, Harvard University Press, Cambridge, 1955, particularly those references listed in Sections 139 (p. 571), 157 (p. 573) and 222-228 (pp. 579 f).

Other applications depend on the various possible frequency spectra of noise. The frequency spectrum is independent of the amplitude distribution, in the sense that a normal distribution of amplitudes is possible with any frequency spectrum - flat, broad, narrow, sloping, or peaked. Systems that affect one characteristic, however, may also affect the other. For example, nonlinear clipping affects both the amplitude distribution and the frequency spectrum. Linear filter networks used on purely random noise do not affect the randomness but alter the frequency characteristic and correspondingly the time scale. Linear filter networks used after clipped noise alter the frequency spectrum and also tend to make the noise more nearly random.

4.7.2 ELECTROACOUSTIC TESTS. The Type 1390-B Random-Noise Generator is a useful signal source for many types of electroacoustic tests, including loud-speaker-response tests. Some useful discussions of these tests using a noise source are given in the following: Leo. L. Beranek, Acoustic Measurements, New York, John Wiley and Sons, 1949, pp. 639-640, 665 f, 697-702; and RMA Standard SE-103, Speakers for Sound Equipment, April 1949, p. 6, Standard Test Signal BA.

Other General Radio instruments useful in electroacoustic tests are the Type 1551 Sound-Level Meter, the Type 1551-P1 Condenser Microphone System, the Type 1558 Octave-Band Noise Analyzer, the Type 1564-A Sound and Vibration Analyzer, and the Type 1521 Graphic Level Recorder.

4.7.3 ROOM ACOUSTICS TESTS. The noise generator is a useful signal source for many types of tests in room acoustics. These include reverberation tests, panel (wall and floor) transmission measurements, measurement of space irregularities, and measurement of steady-state signal transmission. For details, consult the following: Leo. L. Beranek, Acoustic Measurements, New York, John Wiley and Sons, 1949, pp. 804 ff, 826 f, 831 and 883.

The Type 1551-C Sound-Level Meter, the Types 1550-A and 1558-A Octave-Band Analyzers, the Type 1564-A Sound and Vibration Analyzer, and the Type

1521 Graphic Level Recorder are useful elements in the over-all set-up for these tests.

4.7.4 STATISTICAL DEMONSTRATIONS. The properties of noise that concern the amplitude-time relationship are usually described by statistical means². (Refer to paragraph 2.3.)

Random-noise generators can be used to demonstrate some concepts of statistical theory. The equipment and methods for demonstrating various degrees of correlation and possible errors of random sampling are described by J. C. R. Licklider and E. Dzendolet, "Oscillographic Scatterplots Illustrating Various Degrees of Correlation", Science, January 30, 1948, Vol. 107, No. 2770, pp. 121-124.

4.7.5 NOISE AT HIGH FREQUENCIES. The noise generator can be used to modulate an r-f carrier when a noise signal is desired at a frequency above 5Mc. A crystal diode modulator⁸ is a suitable instrument for wide-band modulation, and the Type 1363 VHF Unit Oscillators⁹ and the Type 1362 UHF Unit Oscillators are suitable rf oscillators covering the range from 65 to 920 Mc.

Because of the two sidebands that result from the standard modulation techniques, the noise band can be made to extend over a 10-Mc range, 5 Mc on each side of the carrier. For some applications it may be desirable to use a suppressed-carrier or balanced-type modulator (see Terman, Radio Engineering Handbook, New York, McGraw-Hill Book Co., 1943, pp. 551-553). It is also possible to use a series of carriers and modulators to combine to give a much broader band of noise than 10 Mc.

Some signal generators and oscillators include modulating circuits, so that an external source such as the Type 1390-B Random-Noise Generator can be used to modulate the signal. Instruments of this type are the Types 1003 and 1026 Standard Signal Generators. For these generators the modulation produced is limited to the audio range and to about 5 to 10 percent rms noise modulation, with peaks much higher. When a wider frequency band is desired, an external modulator should be used as described above.

⁸ Byers, W. F., "An Amplitude Modulator for Video Frequencies", General Radio Experimenter, March 1950, Vol. 24, No. 10, pp. 6-8.

⁹ E. Karplus, "V-H-F and U-H-F Unit Oscillators", General Radio Experimenter, May 1950, Vol. 24, No. 12, pp. 7-11.

TYPE 1390-B RANDOM-NOISE GENERATOR

4.7.6 VERY HIGH NOISE LEVELS. When noise levels even higher than those provided by the Type 1390-B Random-Noise Generator are desired, an amplifier should be used.

4.7.7 INTERFERENCE TESTS. Since noise is a common form of interfering or disturbing signal or signal that limits the threshold of detectability, the noise generator can be used to check receivers, communication systems, and detection systems for susceptibility to interference. It can also be used as a training aid for operators who must communicate through interference.

4.7.8 OVER-ALL CALIBRATION TESTS. The noise generator can be used as an over-all calibration device because of the wide frequency range available at the output. This calibration signal can be particularly useful in audio systems that involve a recording technique, and its use can frequently simplify the calibration procedure when an analyzer forms part of the system.¹⁰

For example, when a magnetic tape recorder is used to record a signal to be measured on playback, reference signals must be recorded before and after the unknown signal is recorded. These reference signals permit one to fix levels and to determine response characteristics, which can vary from time to time depending on the condition of the tape and the machine. These reference signals are usually a series of tones at various points in the frequency range of interest. The noise generator, due to the broad frequency band, permits the use of a more versatile reference signal. Thus a useful set of reference signals would be a burst of noise of about one-half minute duration and a burst of a 400-cycle tone of about the same length. These two signals would permit the determination of frequency response, signal-to-noise ratio, harmonic distortion (at one level and one frequency), and flutter.

To determine the frequency response by use of a noise signal, perform the following operations:

1. Set the noise generator to the 20-kc range. Connect it to the input of the system under test, at such a level that the r-m-s input is at least 14 decibels below the sine-wave overload point.

2. Make a frequency spectrum analysis of the input noise signal and of the output noise signal from the device under test. The relative level of input and output as a function of frequency is then the frequency

response of the device under test, unless spurious signals are present in the output of the device.

3. Test for spurious signals by making an analysis of the output with no input signal applied.

When these measurements are made, the input and output must be analyzed by analyzers of the same effective bandwidth. The bandwidth of the analyzer should also be appreciably smaller than the bandwidth of the device under test. Furthermore, the ultimate attenuation of the analyzer should be much greater than variation in response that one expects to measure, so that it will not limit the observed response. Distortion and background noise in the device under test will also limit the range of variation in response that can be measured by this method, and it is therefore important to select the proper level for input signal.

4.7.9 ANALYSIS OF NOISE. In the course of measurements with a noise generator, it is often necessary to make a frequency spectrum analysis of noise. The Type 1900-A Wave Analyzer, the Types 1558-A and 1558-AP Octave-Band Noise Analyzers, and the Type 1564-A Sound and Vibration Analyzer are useful accessories for this analysis in the audio-frequency range. The results of noise analyses by these different analyzers cannot be compared directly; the results must be modified because of the different bandwidths. Refer to paragraph 2.5 for a discussion of the frequency spectrum of noise.

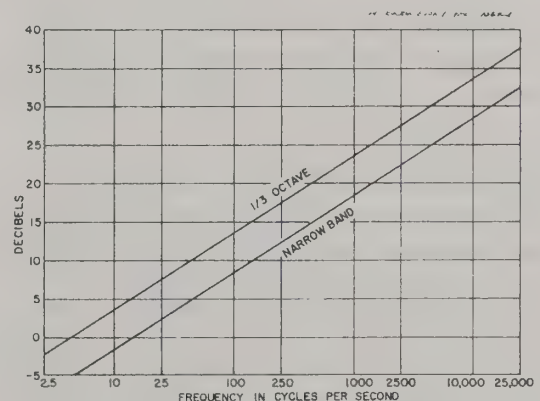


Figure 12. Decibels to Be Subtracted from Type 1564-A Reading to Obtain Spectral-Density Level.

The bandwidths of the Octave-Band Noise Analyzers increase in cycles directly with the mean frequency of the band. For that reason, a noise signal that is uniform in spectral-energy density over the frequency range will give higher-level readings for the higher-frequency bands than for the lower-frequency bands. The following table shows the values to be subtracted from the readings of the analyzer to obtain the spectral-density levels.

¹⁰S. S. Stevens, J. P. Egan, and G. A. Miller, "Methods of Measuring Speech Spectra", *Journal of the Acoustical Society of America*, Vol. 19, No. 5, September 1947, pp. 771-780.

Type 1558-A Band	DB to be sub- tracted	Type 1558-AP Band Center freq.	DB to be sub- tracted
18.75-37.5	13	31.5	13.5
37.5-75	16	63	16.5
75-150	19	125	19.5
150-350	22	250	22.5
350-600	25	500	25.5
600-1200	28	1,000	28.5
1200-2400	31	2,000	31.5
2400-4800	34	4,000	34.5
4800-9600	37	8,000	37.5
9600-19,200	40	16,000	40.5
LP 7.5	18		

The effective bandwidth of the Type 1564-A Sound and Vibration Analyzer increases with increase in the frequency to which the analyzer is tuned. The graph in Figure 12 shows the value in decibels that must be subtracted from the reading of the analyzer to obtain the spectral-density level. This value is determined on the basis of initial calibration of the instrument by a sine-wave signal.

The corrections for spectral density level for the Type 1900-A Wave Analyzer are independent of the center frequency to which it is tuned but do depend on the bandwidth used. For the 3-cycle bandwidth subtract 3.7 db; 10-cycle, subtract 9 db; 50-cycle, subtract 15.9 db to obtain the spectral density level. (These correction numbers take into account the metering characteristic as well as the bandwidth.)

4.7.10 FREQUENCY RESPONSE MEASUREMENT. The noise generator can be used in place of the usual sine-wave generator for measuring the response of circuits and systems. In this application the selective characteristics of generator and detector are reversed from those ordinarily used in point-by-point measurements; the wide-band noise source and a selective detector replace the single-frequency source and wide-band detector. For speech and music circuits, this

technique provides a much closer approximation to operating conditions than does the older system. This approach is particularly useful in testing recording systems.¹⁰ (Refer to paragraph 4.7.8.) The usual sweeping sinusoidal tests are sometimes inconvenient because of the problem of determining the recorded frequency during playback. This problem is eliminated by a recorded noise signal that is analyzed on playback.

Because of its broad frequency spectrum, noise is often used to avoid the marked resonance effects that can occur when vibrations in mechanical structures and acoustical systems are measured. The use of noise as a source in measuring the reverberation characteristics of rooms and the transmission characteristics of building structures results in a type of electrical averaging of the characteristics, provided a reasonably broad band is used. This averaging often simplifies the comparison of the characteristics of different structures.

The noise generator is useful in response measurements on loudspeaker systems in rooms.¹¹ The electrically averaged response can be used to determine the optimum characteristic for equalizing networks, to set the relative levels of woofer and tweeter units, and to adjust levels of multiple-speaker units installed in different locations in a large hall.

4.7.11 RESONANCE TESTS. Because of its broad frequency spectrum, noise can sometimes simplify the search for resonant conditions in a system.¹² The resonance produces a peak in the frequency spectrum, which can be observed in oscillographic displays.

4.7.12 OTHER USES. The noise generator can also be used in crosstalk measurements¹³, for masking crosstalk in multichannel communication systems¹⁴, to drive vibrators in component testing¹⁵, for noise factor comparison tests¹⁶, or distortion measurements¹⁷.

¹¹ L. L. Beranek, Acoustic Measurements, New York, John Wiley, 1949, pp. 665-668 and 697-702.

¹² Emory Cook, "White-Noise Testing Methods", Audio Engineering, Vol. 34, No. 3, March 1950, pp. 13-15.

¹³ J. P. Vasseur, "Les faisceaux hertziens a courants porteurs devant les recommandations du C.C.I.F.", Annales de Radioelectricite, Vol. 9, No. 35, January 1954, pp. 47-82 and EIA Standard RS-252, "Base band Characteristics of the Microwave Radio and Multiplex Equipment," October, 1961.

¹⁴ A. J. Aikens and C. S. Thaeler, "Noise and Cross-talk on N1 Carrier Systems", Electrical Engineering, Vol. 72, No. 12, December 1953, pp. 1075-1080.

¹⁵ J. Robbins, "Standardized White Noise Tests", Elec-

tronic Industries & Tele-Tech, Vol 16, No. 2, February, 1957, pp. 68-69.

S. H. Crandall, ed., Random Vibration, Cambridge, Massachusetts, The Technology Press of MIT, 1958.

¹⁶ IRE "Standards on Electron Devices: Methods of Measuring Noise", Proceedings of the IRE, Vol. 41, No. 7, July 1953, pp. 891-896.

¹⁷ A. P. G. Peterson, "Intermodulation Distortion," 1957 IRE National Convention Record, Vol. 5, Part 7, March, 1957, pp 51-58.

J. S. Murray and J. M. Richards, "Non-linearity Distortion Measurements," Wireless World, Vol. 69, No. 4, April, 1963, pp 161-165.

Section 5

SERVICE AND MAINTENANCE

5.1 SERVICE. The product warranty stated above attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone our Service Department (see rear cover), giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial and type numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department or nearest Sales Engineering Office, requesting a "Returned Material Tag." Use of this tag will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

5.2 MINIMUM-PERFORMANCE STANDARDS.

5.2.1 Equipment Required.

A true-rms ac voltmeter, such as the Hewlett-Packard Model 3400 or equivalent, is required for the following minimum-performance tests. (A 776-A BNC-to 274 Patch Cord can be used to connect the Model 3400 Voltmeter to the 1390-B.)

5.2.2 OPEN-CIRCUIT OUTPUT-VOLTAGE TEST.

a. Connect the rms voltmeter to the OUTPUT terminals of the 1390-B.

b. Set the 1390-B as follows:

RANGE ----- 20 kHz

MULTIPLY BY ----- 1.0

LOW-HIGH ----- HIGH

OUTPUT ----- Fully clockwise

POWER ----- ON

c. Both the rms voltmeter and the panel voltmeter on the 1390-B should read 3.0 V or higher.

d. Change the RANGE switch to 500 kHz. The voltmeters should now read 2.0 V or higher.

e. Set the RANGE switch to 5 MHz. The voltmeters should now read 1.0 V or higher.

5.2.3 OUTPUT ATTENUATOR CHECK, 20 kHz.

a. Set the 1390-B as follows:

RANGE ----- 20 kHz

MULTIPLY BY ----- 1.0

LOW-HIGH ----- HIGH

b. Connect the rms voltmeter to the OUTPUT terminals of the 1390-B and set the OUTPUT control

to give a reading of 3.0 V on the 1390-B meter. Note the reading of the rms voltmeter.

c. Set the MULTIPLY BY switch to 0.1 and reset the OUTPUT control for 3.0 V on the 1390-B meter. The rms voltmeter should now read 1/10, $\pm 3\%$ of the previous reading.

d. Repeat this check with the MULTIPLY BY switch at .01, .001, and .0001. The rms voltmeter readings should drop by a factor of 10, $\pm 3\%$ for each step.

5.2.4 OUTPUT ATTENUATOR CHECK, 5 MHz.

a. Set the 1390-B as follows:

RANGE ----- 5 MHz

MULTIPLY BY ----- 1.0

LOW-HIGH ----- HIGH

b. Set the OUTPUT control for a reading of 1.0 V on the 1390-B meter. Follow the procedure of para.

5.2.3 except allow a $\pm 10\%$ tolerance for each step.

5.2.5 HIGH-LOW CHECK.

a. Set the 1390-B as follows:

RANGE ----- 20 kHz

MULTIPLY BY ----- 1.0

LOW-HIGH ----- HIGH

b. With the rms voltmeter connected to the OUTPUT terminals on the 1390-B, set the OUTPUT control for a reading of 3.0 V on the rms voltmeter.

c. Change the HIGH-LOW switch to LOW. The rms voltmeter should now read between 0.3 and 0.6 V.

5.3 ACCESS TO COMPONENTS. To remove the shield, loosen the two fluted locking screws on the back of the instrument. These will unlock on the first turn, but should be loosened the maximum amount before the shield is removed. Pull the shield straight back from the panel.

5.4 PRELIMINARY CHECKS. If the noise generator is inoperative, make the following checks before removing the case. Make sure that the ac supply is plugged into a live power line, that the power switch is turned to the POWER position, that the output control is turned up, that the time-delay relay is operative, and that the fuses are not open.

5.5 TUBE REPLACEMENT. Since the vacuum tubes have a shorter life on the average than the other com-

GENERAL RADIO COMPANY

ponents used in the instrument, they should be tested if the instrument is still inoperative after the above checks have been made.

The Type 6D4 Gas Triode used as the noise source is aged and selected for uniformity of the noise spectrum and for good amplitude characteristics. If the tube has deteriorated and must be replaced, some selection among different tubes of this type may be necessary to find a satisfactory replacement. Use a tube by the same manufacturer.

5.6 HEATER VOLTAGE OF TYPE 6D4 GAS TUBE. The potentiometer at the rear of the chassis is for setting the heater voltage of the gas tube. Over certain ranges of heater voltage, some gas tubes will "sputter". The meter indication on the 20-kc range will often reveal this sputter. Under normal conditions, the meter reading fluctuates two or three percent. When sputtering occurs; the meter reading may fluctuate 10 percent or more. The sputtering is more easily detected by observation of the noise pattern on an oscilloscope or by ear with a good pair of earphones. The heater voltage should be set so that this sputtering does not occur. Some selection among tubes of this type may be necessary to find a tube that is free from sputtering.

5.7 VOLTAGE MEASUREMENTS. The adjacent tables give test voltages for aid in troubleshooting:

T1 TRANSFORMER MEASUREMENTS

Between Terminals	AC Volts
10 and 11	120
5 and 6	17
6 and 7	17
8 and 9	6.3

5.8 VOLTMETER CALIBRATION. To calibrate the voltmeter proceed as follows:

- Remove all external connections from the Type 1390-B, including the power cable.
- Zero the mechanical zero of the meter.
- Set the OUTPUT control fully clockwise.
- Set the MULTIPLY BY switch to 1.0.
- Apply 3.0 volts at 1KC from the GR Type 1304-B or equivalent to the Type 1390-B output terminals. The meter must read upscale.
- Adjust potentiometer R103 (Figure 10) to obtain a reading of 3.3 on the panel voltmeter.
- Apply 3.0 volts at 500KC from an oscillator with low distortion, using open leads, to the Type 1390-B output terminals and observe that the meter reads between 3.2 and 3.4.
- Apply 3.0 volts at 5Mc, using open leads, and observe that the meter reads between 3.0 and 3.6.

TABLE OF VOLTAGES

TUBE	PIN	VOLTS	TUBE	PIN	VOLTS
V1 (3-4)	2	13.4	V3 (6AQ5) (cont.)	6	150 (A)
	7	6.3			150 (B)
V2 (6D4)	3	6.3			110 (C)
	4	0	V4 (6AQ5)	1	0
	7	16.0		2	13
V3 (6AQ5)	1	0		3 to 4	6.3 ac
	2	5.5		5	165
	3	20		6	245
	4	13.4	V5 (115NO30T)	4	120 ac*
	5	230 (A) 215 (B) 45 (C)		9	120 ac*

NOTES

Voltages are measured with a 20,000-ohms-per-volt voltmeter and are dc with respect to ground unless otherwise stated.

- (A) S3 = 5 Mc
(B) S3 = 500 kc
(C) S3 = 20 kc

* Voltages are measured with a 1000 Ω /volt rectifier meter, and are with respect to terminal 11 on transformer T1.

TYPE 1390-B RANDOM-NOISE GENERATOR

ELECTRICAL PARTS LIST

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
CAPACITORS					
C1	Electrolytic, 25/25 μ F 200 V	4450-3300	37942	104110G1S3C1X1	5910-978-2426
C2	Electrolytic, 50/25/25 μ F 450 V	4450-0800	56289	D28936	5910-970-1589
C3	Electrolytic, 50/25/25 μ F 450 V	4450-0800	56289	D28936	5910-970-1589
C4	Electrolytic, 1500/750/750 μ F 25 V	4450-0700	90201	203828S10C10X2	5910-976-9415
C5	Ceramic, 1.0 pF $\pm 10\%$	4400-0100	78488	GA, 1.0 pF $\pm 10\%$	5910-981-3425
C6	Plastic, 47 μ F $\pm 10\%$	4860-5800	84411	663UW, 47 μ F $\pm 10\%$	5910-961-6230
C7	Electrolytic, 15 μ F 300 V	4450-1600	37942	204009854C2X2	5910-034-5370
C8	Electrolytic, 50/25/25 μ F, 450 V	4450-0800	56289	D28936	5910-970-1589
C9	Mica, 845 pF, $\pm 2\%$, 500 V	4690-4073	00656	CM20E, 845 pF, $\pm 2\%$	
C10	Mica, 470 pF $\pm 10\%$	4660-5400	72136	CM-15E, 470 pF $\pm 10\%$	5910-668-5732
C11*	Mica, 0.0033 μ F, $\pm 10\%$, 500 V	4570-1333	14655	5A, 0.0033 pF, $\pm 10\%$	
C12	Mica, 300 pF $\pm 10\%$	4660-4600	72136	CM-15E, 300 pF $\pm 10\%$	5910-034-5426
C13	Ceramic, .01 μ F $\pm 80-20\%$	4406-3109	72982	811, 000X5U103X	5910-754-7049
C14	Trimmer, 5-20 pF	4910-0400	72982	TS2AN300, 5-20 pF	5910-034-5429
C15	Plastic, .33 μ F $\pm 10\%$	4860-5700	84411	620S033 MFPORM	5910-950-3296
C16	Electrolytic, 1500/750/750 μ F 25 V	4450-0700	90201	203828S10C10X2	5910-977-7579
C17	Ceramic, .01 μ F $\pm 80-20\%$	4406-3109	72982	811, 000X5U103X	5910-754-7049
C18	Ceramic, 50 pF $\pm 10\%$	4400-4400	72982	315N750, 50 pF $\pm 10\%$	5910-976-9413
C19	Ceramic, 50 4570-13	4400-4400	72982	315N750, 50 pF $\pm 10\%$	5910-976-9413
C20	Ceramic, 50 pF $\pm 10\%$	4400-4400	72982	315N750, 50 pF $\pm 10\%$	5910-976-9413
C21	Mica, 470 μ F, $\pm 10\%$, 500 V	4660-5400	72136	CM15E, 470 pF	5910-034-5425
C22	Ceramic, 68 pF, $\pm 10\%$, 500 V	4404-0688	72982	831, 68 pF $\pm 10\%$	
C23	Ceramic, 470 pF, $\pm 5\%$, 500 V	4404-1475	72982	831, 470 pF, $\pm 5\%$	
C100	Ceramic, 6.8 pF $\pm 5\%$	4400-0680	78488	GA, 6.8 pF $\pm 5\%$	
C101	Electrolytic, 100 μ F, 15 V	4450-2800	56289	D17872	5910-034-5368
C102	Electrolytic, 100 μ F, 15 V	4450-2800	56289	D17872	5910-034-5368
DIODES					
CR100	Diode, Type 1N995	6082-1002	80368	1N995	
CR101	Diode, Type 1N995	6082-1002	80368	1N995	
RESISTORS					
R1	Power, 470 Ω $\pm 5\%$	6640-1479	24655	6640-1479	5905-712-8330
R2	Power, 330 Ω $\pm 5\%$	6640-1339	24655	6640-1339	5905-977-7584
R3	Power, 220 Ω $\pm 5\%$	6640-1229	24655	6640-1229	5905-977-7585
R4	Composition, 5.1 k Ω $\pm 10\%$	6110-2515	01121	RC32GF512J	5905-279-2591
R5	Composition, 10 k Ω $\pm 10\%$	6120-3109	01121	HB, 10 k Ω $\pm 10\%$	
R6	Composition, 10 k Ω $\pm 10\%$	6120-3109	01121	HB, 10 k Ω $\pm 10\%$	
R7	Composition, 56 Ω $\pm 5\%$	6100-0565	01121	RC20GF560J	5905-279-1897
R8	Pot, Wirewound, 500 Ω , $\pm 10\%$	6050-1100	12697	43WX, 500 Ω	5905-797-1056
R9	Composition, 150 k Ω $\pm 5\%$	6100-4155	01121	RC20GF154J	5905-279-2522
R10	Composition, 16 k Ω $\pm 5\%$	6100-3165	01121	RC20GF163J	5905-279-3501
R11	Composition, 330 Ω $\pm 5\%$	6100-1335	01121	RC20GF331J	5905-192-3971
R12	Power, 100 Ω $\pm 5\%$	6640-1105	75042	1 3/4A 12 AB, 100 Ω $\pm 5\%$	5905-977-7582
R13	Composition, 2.2 k Ω $\pm 5\%$	6100-2225	01121	RC20GF222J	5905-279-1876
R14	Composition, 56 Ω $\pm 5\%$	6100-0565	01121	RC20GF560J	5905-279-1897
R15	Composition, 56 k Ω $\pm 5\%$	6100-3565	01121	RC20GF563J	5905-171-1986
R16	Composition, 330 Ω $\pm 5\%$	6100-1335	01121	RC20GF331J	5905-192-3971
R17	Composition, 68 Ω $\pm 5\%$	6100-0685	01121	RC20GF680J	5905-195-5571
R18*	Composition, 22 k Ω $\pm 5\%$	6100-3225	01121	RC20GF223J	5905-171-2004
R19	Power, 2.2 k Ω $\pm 5\%$	6640-2225	24655	6640-2225	5905-034-5382
R20	Composition, 470 k Ω $\pm 5\%$	6100-4475	01121	RC20GF474J	5905-279-2515
R21	Composition, 56 Ω $\pm 5\%$	6100-0565	01121	RC20GF560J	5905-279-1897
R22	Composition, 180 Ω $\pm 5\%$	6100-1185	01121	RC20GF181J	5905-279-3514
R23	Composition, 150 Ω $\pm 5\%$	6100-1155	01121	RC20GF151J	5905-299-1541
R24	Power, 15 k Ω $\pm 5\%$	6660-3155	75042	AS-5, 15 k Ω $\pm 5\%$	
R25	Composition, 1 k Ω $\pm 5\%$	6110-2109	01121	GB, 1 k Ω $\pm 5\%$	
R26	Composition, 1 k Ω $\pm 5\%$	6100-2105	01121	RC20GF102J	5905-195-6806
R27	Composition, 220 Ω $\pm 5\%$	6100-1225	01121	RC20GF221J	5905-279-3513
R28	Composition, 5.1 k Ω $\pm 10\%$	6110-2515	01121	RC32GF512J	5905-279-2591
R32	Power, 1.5 Ω $\pm 5\%$	6640-9155	24655	6640-9155	
R33	Potentiometer, 2.5 k Ω $\pm 10\%$	6000-0400	12697	53MS, 2.5 k Ω $\pm 10\%$	5905-034-5378
R34	Wire Wound, 5.8 Ω $\pm 10\%$	6760-9689	75042	BWH, 6.8 Ω $\pm 10\%$	5905-930-2613
R35	Film, 2 k Ω $\pm 1\%$	6350-1200	75042	CEB, 2 k Ω $\pm 1\%$	5905-538-3516
R36	Film, 2 k Ω $\pm 1\%$	6350-1200	75042	CEB, 2 k Ω $\pm 1\%$	5905-538-3516
R37	Film, 2 k Ω $\pm 1\%$	6350-1200	75042	CEB, 2 k Ω $\pm 1\%$	5905-538-3516
R38	Film, 2 k Ω $\pm 1\%$	6350-1200	75042	CEB, 2 k Ω $\pm 1\%$	5905-538-3516
R39	Film, 2 k Ω $\pm 1\%$	0700-3520	24655	0700-3520	5905-885-0362
R40	Film, 2 k Ω $\pm 1\%$	0700-3520	24655	0700-3520	5905-885-0362
R41	Film, 2 k Ω $\pm 1\%$	0700-3520	24655	0700-3520	5905-885-0362
R42	Film, 2 k Ω $\pm 1\%$	0700-3510	24655	0700-3510	5905-885-0363
R43*	Comp., 1 k Ω , $\pm 5\%$	6099-2105	75042	BTS, 1 k Ω , $\pm 5\%$	5905-681-6422
R100	Composition, 2.7 k Ω $\pm 5\%$	6100-2275	01121	RC20GF272J	5905-279-1880
R101	Composition, 4.3 k Ω $\pm 5\%$	6100-2435	01121	RC20GF432J	5905-257-0935
R102	Composition, 5.1 k Ω $\pm 5\%$	6100-2515	01121	RC20GF512J	5905-279-2019
R103	Potentiometer, Composition, 5 k Ω $\pm 20\%$	6040-0600	01121	FWC, 5 k Ω $\pm 20\%$	5905-034-5374

* Factory may have added a shunt component. If tube V2 is replaced, it may be necessary to remove the shunting component

GENERAL RADIO COMPANY

ELECTRICAL PARTS LIST (cont)

Ref Des	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
MISCELLANEOUS					
F1	Fuse, 115 V	5330-1100	71400	MDL, 0.6 Amp	5920-280-3161
	Fuse, 230 V	5330-0800	71400	MDL, 0.3 Amp	5920-235-8362
F2	Fuse, 115 V	5330-1100	71400	MDL, 0.6 Amp	5920-280-3161
	Fuse, 230 V	5330-0800	71400	MDL, 0.3 Amp	5920-235-8362
J1	Binding Post	0938-3000	24655	0938-3000	
J2	Binding Post	0938-3022	24655	0938-3022	
L1	Inductors, 22 μ H \pm 10%	4300-2600	99800	1537, 22 μ H \pm 10%	5950-668-5867
L2	56000 μ H \pm 10%	4300-6397	24759	CHM=56,000 μ H	5950-586-3459
L3	Inductors, .5 mH	4290-4700	42498	R50, .5 mH	5950-794-3455
L4	Choke Air Core, 0.5 mH	4290-4700	42498	R50, 0.5 μ H	
M1	Meter	5730-0920	24655	5730-0920	6625-882-3153
P1	Pilot Light	5600-0700	24454	MAZDA, 44	6240-057-2887
RX1	Rectifier	6081-1002	09213	1N3254	5961-082-3988
RX2	Rectifier	6081-1002	09213	1N3254	5961-082-3988
RX3	Rectifier	6081-1001	79089	1N3253	5961-814-4251
RX4	Rectifier	6081-1001	79089	1N3253	5961-814-4251
S1	Switch	7910-1300	04009	83053-SA	5930-909-3510
S2	Switch	7890-1800	76854	Type HC	5930-357-1599
S3	Switch	7890-1810	76854	Type HC	5930-289-9872
S4	Switch	7890-1820	76854	Type HC	5930-289-9873
T1	Transformer	0485-4970	24655	0485-4970	5950-994-4580
V1	Tube	8330-0300	70563	3-4	
V2 *	Tube	8360-8110	33173	6D4	
V3	Tube	8360-1500	24446	6AQ5	
V4	Tube	8360-1500	24446	6AQ5	5960-166-7673
V5	Tube	8370-1100	70563	115N030T	5945-606-2903

* For Instruments with ID # 4627 or higher, the Sylvania 6D4 tube (P/N 8360-4500) has been replaced by a G.E. 6D4 tube (P/N 8360-8110). Always make replacements with tubes of the same manufacturer.

MECHANICAL PARTS LIST

Name	Description	GR Part No.	Fed Mfg Code	Mfg Part No.	Fed Stock No.
Etched Circuit Asm. Comp.		1390-2700	24655	1390-2700	
Switch Assembly		1390-3040	24655	1390-3040	
Power Cable		4200-9622	24655	4200-9622	6150-968-0081
Connector, Power Plug		4240-0600	24655	4240-0600	5935-816-0254
Dust Cover Assembly		4429-0400	24655	4429-0400	
Feet, Black Neophrene		5260-0700	24655	5260-0700	5340-738-6329
End Frame Asm, Right		5310-4086	24655	5310-4086	
End Frame Asm, Left		5310-4087	24655	5310-4087	
Knob, Bar		5520-5320	24655	5520-5320	
Knob, OUTPUT		5520-5321	24655	5520-5321	
Pilot Light, Lens		5620-0300	72765	25P Unfluted PSP-70	6210-299-3902
Pilot Light Socket Asm.		7510-1930	24655	7510-1930	6210-475-9501
Fuse holder		5650-0100	71400	HKP-H	5920-284-7144

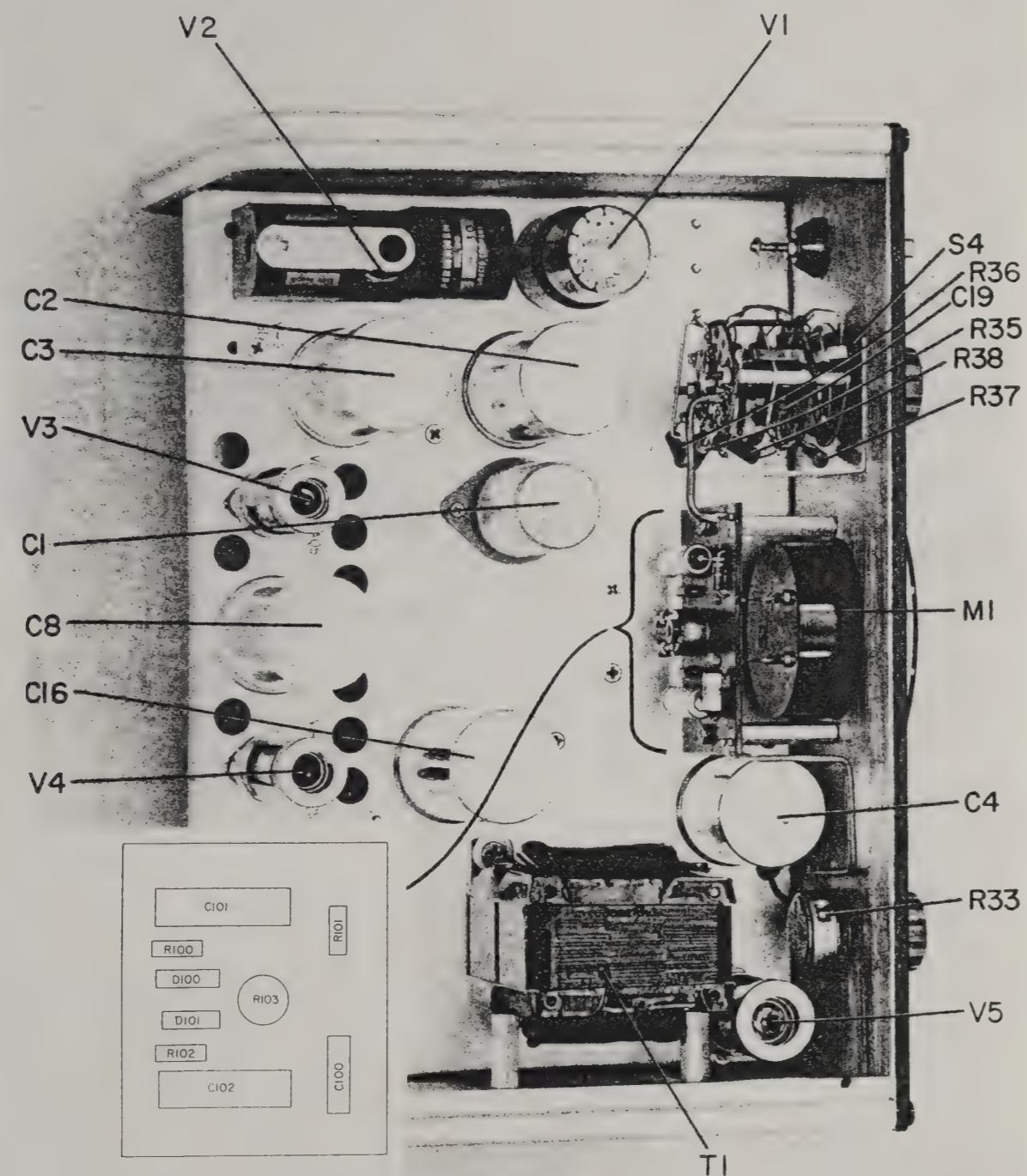


Figure 10. Top Interior View.

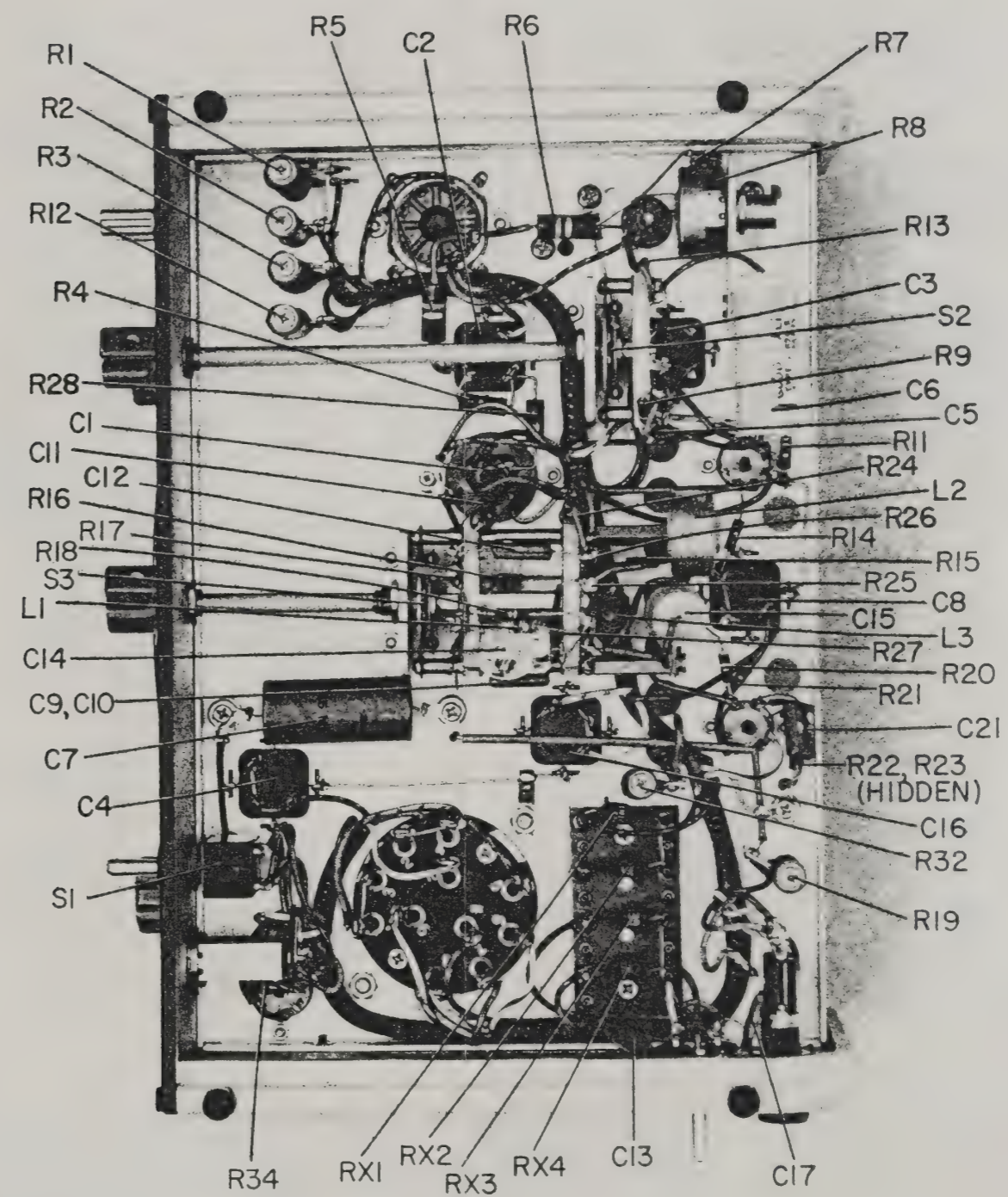
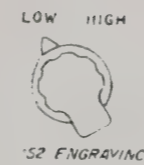
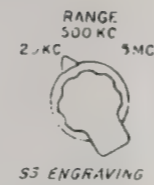
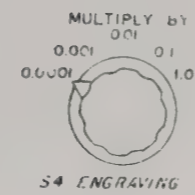


Figure 11. Bottom Interior View.

GR-1390 15

TYPE 1390-B RANDOM-NOISE GENERATOR

Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.



POWER
DELAYED ON

OFF
SI ENGRAVING

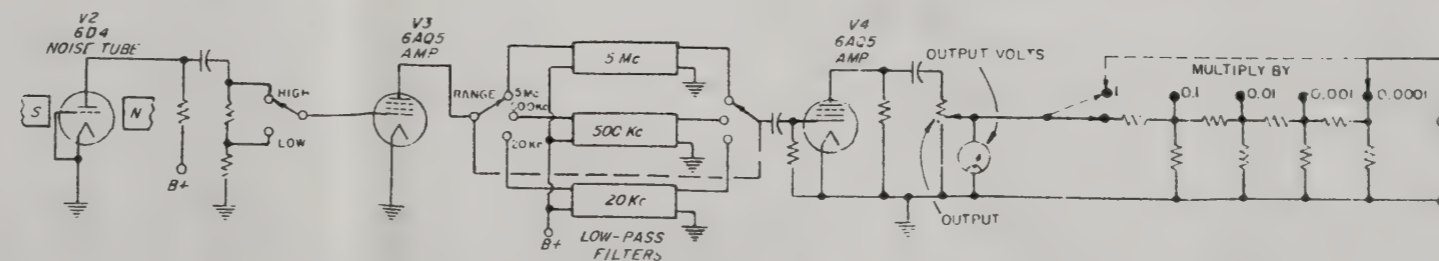
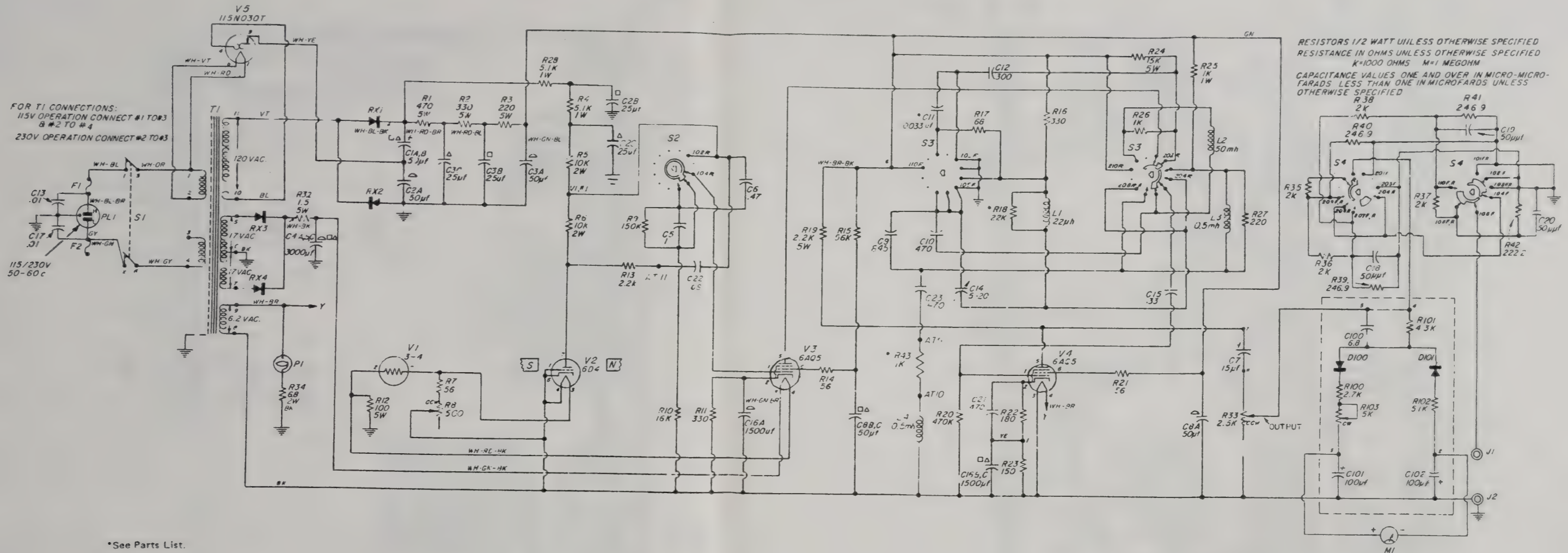


Figure 13. Schematic Wiring Diagram.

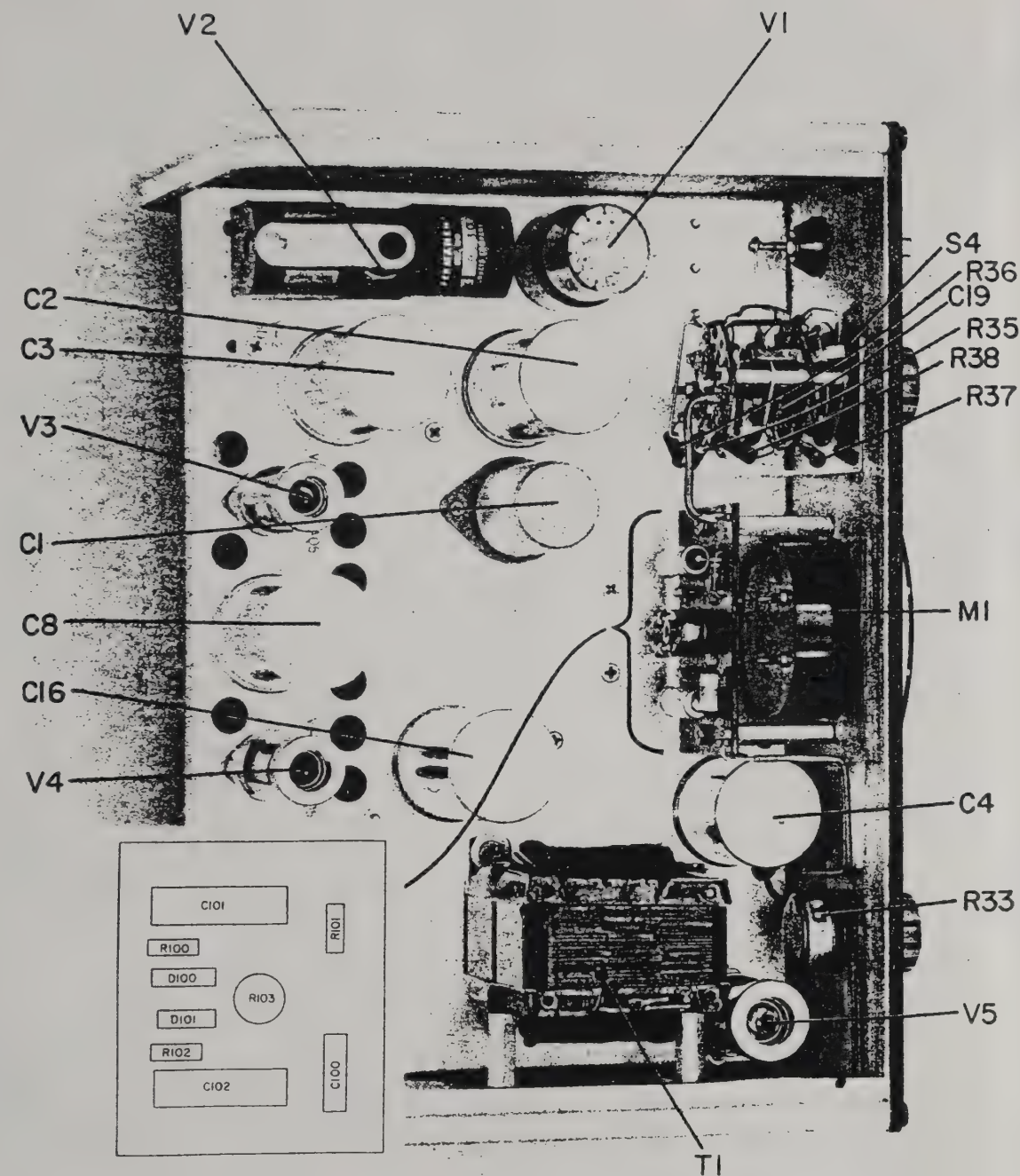


Figure 10. Top Interior View.

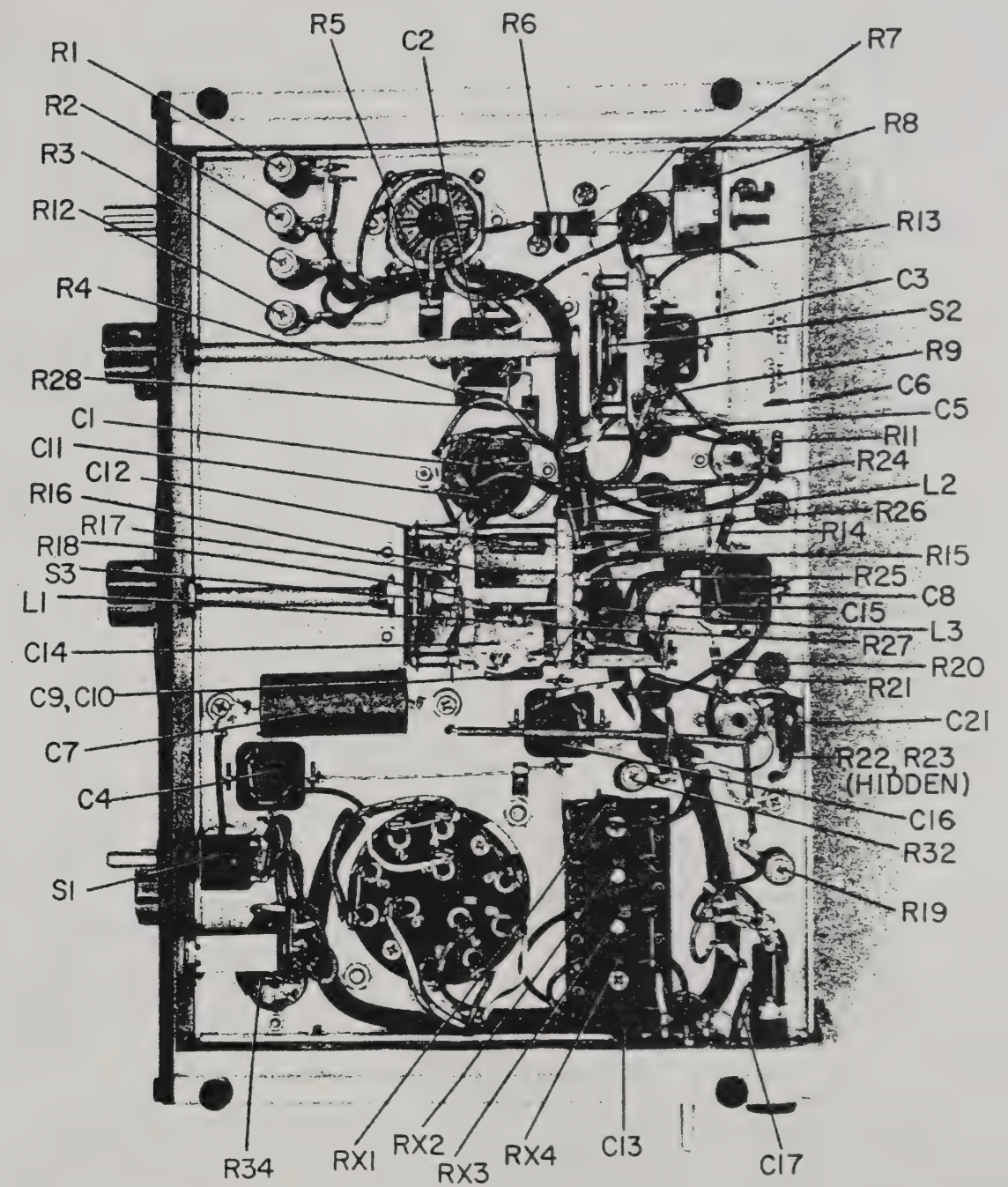


Figure 11. Bottom Interior View.

GR-1390 B

TYPE 1390-B RANDOM-NOISE GENERATOR

Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.

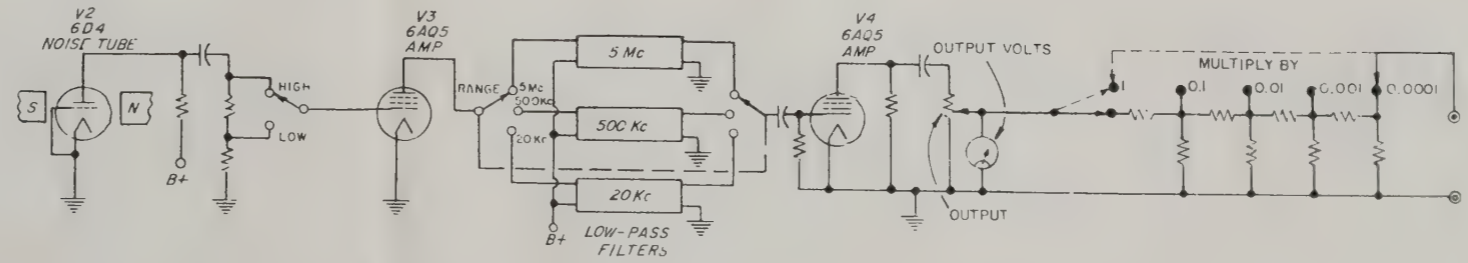
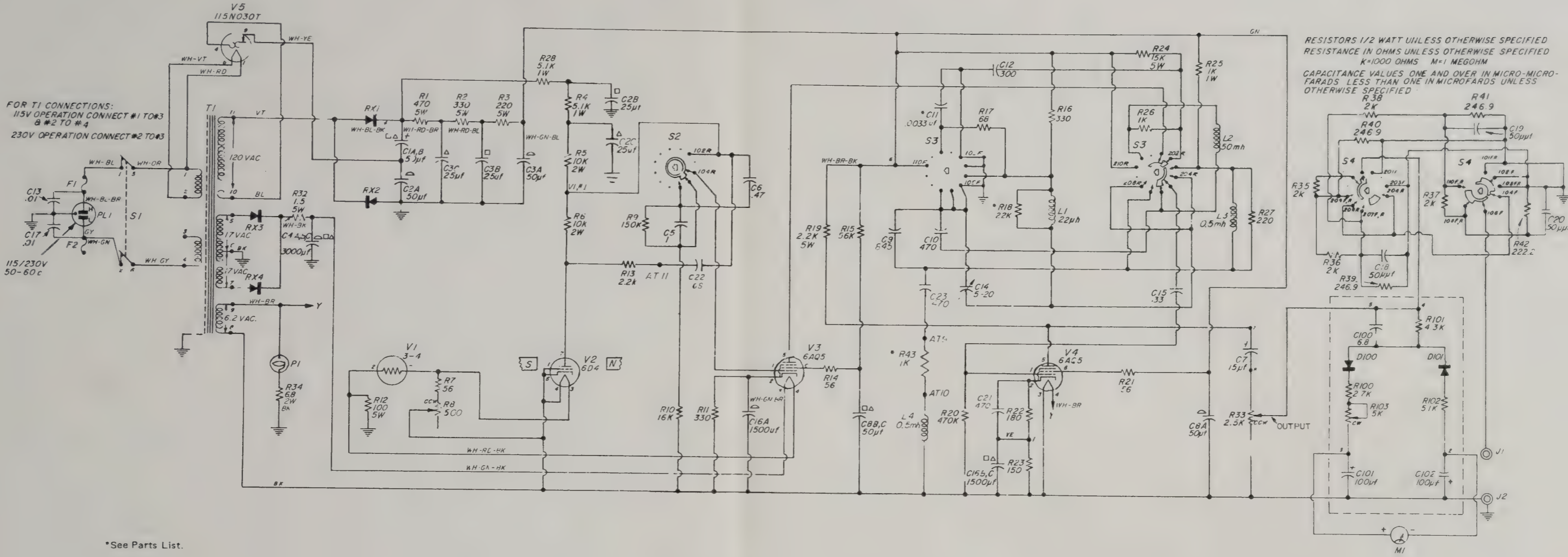
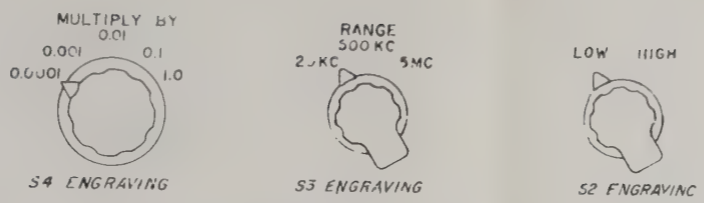
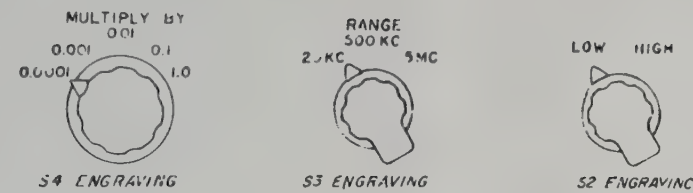


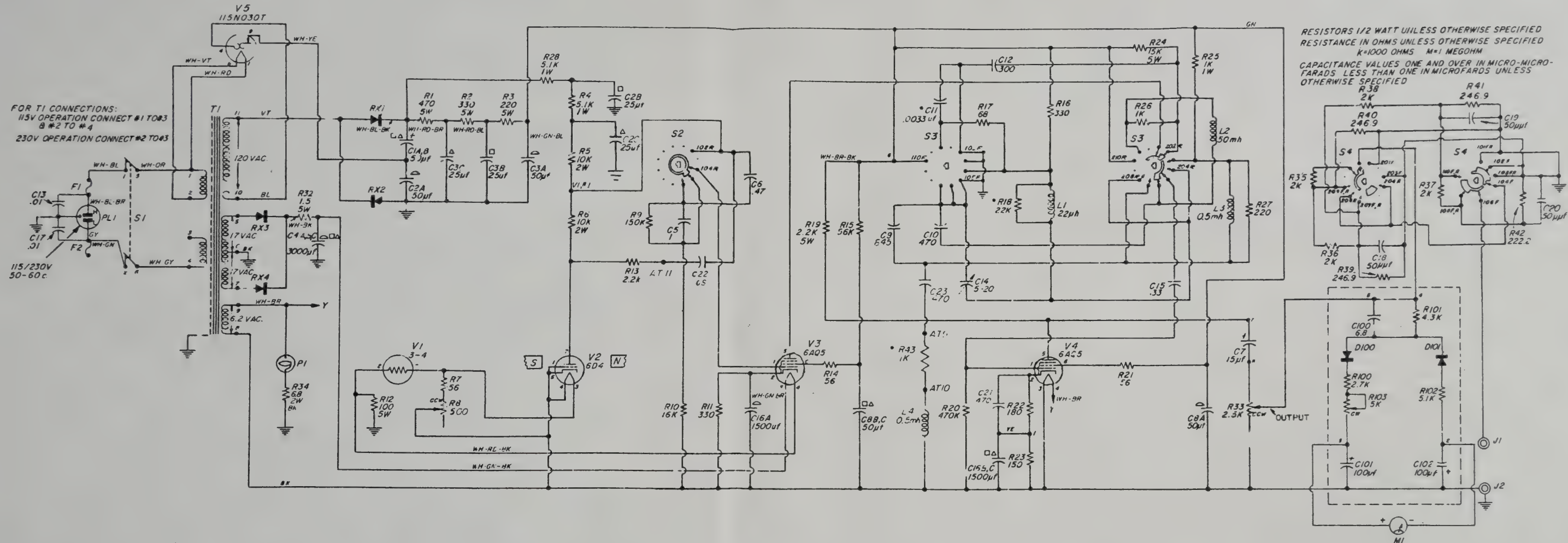
Figure 13. Schematic Wiring Diagram.

Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.



POWER
DELAYED ON

OFF
S1 ENGRAVING



*See Parts List.

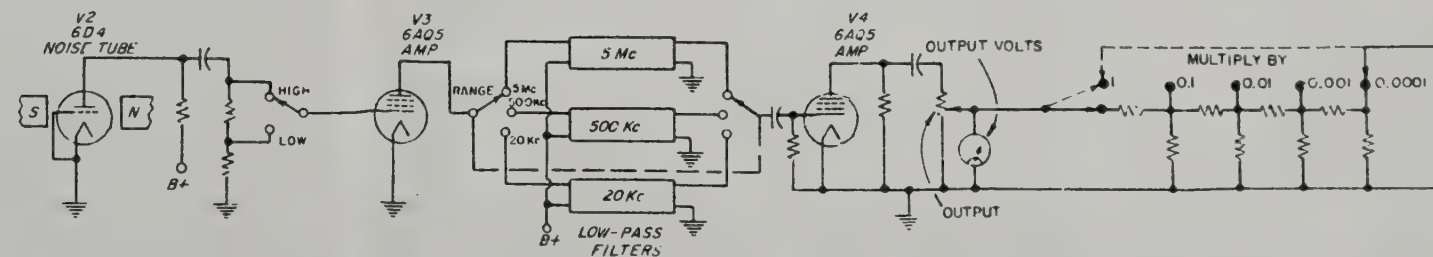


Figure 13. Schematic Wiring Diagram.

OPERATING INSTRUCTIONS

TYPE 1521-A

GRAPHIC LEVEL RECORDER

Form 1521-0110-E
October, 1963

Copyright 1961 by General Radio Company
West Concord, Massachusetts, USA

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

SS

Insert
Foldout/Map
Here

OPERATING INSTRUCTIONS

TYPE 1521-A

GRAPHIC LEVEL RECORDER

Form 1521-0110-E
October, 1963

Copyright 1961 by General Radio Company
West Concord, Massachusetts, USA

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

LIST OF ILLUSTRATIONS

Figure	Title	Page
1.1	Type 1521-A Graphic Level Recorder	vi
1.2	Block Diagram of Recorder	1
1.3	Accessories Supplied.	3
1.4	Type 1521-9427 Chart Paper	5
1.5	Type 1521-9463 Chart Paper	5
2.1	Front Oblique View of Recorder	6
2.2	Top View of Recorder.	7
2.3	Recorder Attached to Type 1304-B Beat-Frequency Audio Generator	9
2.4	Recorder Attached to Type 1564-A Sound and Vibration Analyzer	9
2.5	Connections for Three-Terminal AC Measurements	9
3.1	Recorder Attached to Type 1900-A Wave Analyzer	14
4.1	View of Magnetic Structure and Pen Motor	16
4.2	Block Diagram of Servo Loop for DC Recording	16
4.3	Recording of Ramp-Type Input.	17
4.4	Dynamic Error for Ideal Ramp Input	17
4.5	Dynamic Error for 20-, 40-, and 80-db Potentiometers	17
4.6	Dynamic Error for Various Writing Speeds (with 40-db Potentiometer)	18
4.7	Minimum-Reverberation-Time Measurements	19
4.8	Servo Frequency Response	19
4.9	Servo Bandwidth vs Amplitude of Excursions	20
4.10	Errors from Sweeping High-Q Analyzer Too Fast	21
5.1	Recording of Noise Level in a Cafeteria	23
5.2	Direct Connection of Microphone to Recorder	24
5.3	Conversion of Chart Paper from db to RMS Values of Velocity, Acceleration, and Amplitude	24
5.4	Decay Rate for 1/3-Octave Band of Noise at 500 cps	25
5.5	Reverberation Time for 1/3-Octave Band of Noise at 500 cps.	25
5.6	Setup for Reverberation Measurements	25
5.7	Setup for Portable Reverberation Measurements	26
5.8	Recording of Frequency Response of a Public-Address System	28
5.9	Recording of Transmission Characteristics of an Adjustable Notch Filter for Four Different Frequency Settings	28
5.10	Use of Recorder to Control Sound Level for Microphone Calibration.	29
5.11	Setup for Microphone Calibration	30
5.12	System used to Measure Ratio of Output to Input as a Function of Frequency	31
5.13	Detector Circuit Diagram	31
6.1	Bottom View.	35
6.2	Schematic Diagram	37

TABLE OF CONTENTS

Section 1 INTRODUCTION	1
1.1 Purpose	1
1.2 General Description	1
1.3 Writing Speed	2
1.4 Paper Speed	2
1.5 Accessories	2
Section 2 INSTALLATION	6
2.1 General.	6
2.2 Level-vs-Frequency Recording	8
2.3 DC Recording.	10
Section 3 OPERATING PROCEDURE	10
3.1 Controls	10
3.2 General Operation	10
3.3 Level-vs-Time Recording	13
3.4 Level-vs-Frequency Recording	13
3.5 DC Recording.	14
Section 4 PRINCIPLES OF OPERATION.	15
4.1 General.	15
4.2 Input Circuit and AC Amplifier	15
4.3 Detector	15
4.4 Pen Drive Circuit	15
4.5 Velocity Feedback	16
4.6 Logarithmic Potentiometers	16
4.7 DC Recording.	16
4.8 Transient Response and Dynamic Error	16
4.9 Accuracy of Null (Static Accuracy).	18
4.10 Servo Bandwidth	19
4.11 High-Q Analyzers	20
Section 5 APPLICATIONS.	22
5.1 General.	22
5.2 Use with Sound-Level Meter	22
5.3 High-Level Sounds	23
5.4 Vibration Level vs Time	23
5.5 Reverberation Time and Decay Rate	24
5.6 VU Recordings	26
5.7 Frequency Response Measurements using Type 1304-B Beat-Frequency Generator	27
5.8 Frequency Response Measurements of Phonograph Reproducers	27
5.9 Constant Sound-Pressure Level	27
5.10 Direct Comparison of Levels	30
5.11 Frequency Analysis	31
Section 6 SERVICE AND MAINTENANCE.	32
6.1 General.	32
6.2 Cleaning and Lubrication	32
6.3 Overshoot and Creep Adjustments	32
6.4 Trouble-Shooting Procedure	33
6.5 Other Service Problems	34

LIST OF TABLES

Table	Title	Page
1.1	Accessories Supplied	2
1.2	Accessories Available	4
2.1	Potentiometer Input-Level Ranges	7
3.1	Controls on the Recorder	11
3.2	Connectors on the Recorder	11
3.3	Controls on Recorder Accessories	12
3.4	Maximum Recommended Sweep Speeds for Types 760-B and 1554-A Sound Analyzers	13
3.5	Industry Scale Factors	15
4.1	Recorder Drift Characteristics	19
4.2	Servo Bandwidth for Slow Writing Speeds	20
4.3	Errors at Maximum Recommended Sweep Speeds	21
5.1	Range of Sound Levels with Sound-Level Meter or Direct Microphone Connection	23
5.2	Tape-Recording Level for Reverberation-Time Measurements	26
5.3	Speed Characteristics for VU Measurement	27
5.4	Equipment Needed to Provide Constant Sound Pressure Level	29
5.5	Source Level Variations	30
6.1	Trouble-Shooting Chart	33
6.2	DC Voltage and Resistance Chart	34
	Parts List	36

Special Request to the User of This Instrument

We believe that the most effective way to make our products more useful is to learn from the experience and opinions of those who use them. For this reason we have included a questionnaire at the rear of this manual. Your answers to the questions contained, based on your experience in using this instrument, will be of great value to General Radio engineers and other personnel concerned with new products. Such comments will have a strong influence on the direction of future development work. The resulting better products will benefit our customers as well as ourselves.

The questionnaire is in its own postage-paid envelope. Simply fold as directed, staple, and mail.

Any information you supply will not go outside our Company without your specific authorization. Your reply will be acknowledged, and your questions answered by GR engineers concerned with this instrument. May we have your comments?

SPECIFICATIONS

Range: With potentiometer furnished, 0 to 40 db level recording (20-db and 80-db potentiometers available); 0 to 0.8 volt (at 1000 ohms) full scale dc recording with zero input position adjustment.

Response

Recorder: 20 cps to 200 kc (within 3 db).

Order: 0 to 10 cps (peak-to-peak amplitude 25% of full scale).

Potentiometer Linearity

Recorder: $\pm 1\%$ of full-scale db value plus a error of 0.5 db at 100 kc and 1.5 db at 200 kc.

Order: $\pm 1\%$ of full scale.

Accuracy: $\pm 0.25\%$ of full scale.

Input Voltage: 100 volts, ac.

Attenuator: 60 db in 10-db steps.

Impedance: 10,000 ohms for ac level recorder; 100 ohms for dc recorder.

Sensitivity: 1 millivolt at 0 db for level recorder; 3 volt full scale for dc recording.

Speeds: 2.5 inches per minute to 75 inches per minute.

A slow-speed motor to provide speeds of 1/100 inch per hour is available as an alternate.

Speed: 1, 3, 10, or 20 inches per second (or 1/100 inch per hour), with overshoot less than 1 db.

Motor or Analyzer Drive: Order Type 1521-P10B and appropriate link unit.

DC Reference: Internal terminals are provided for an external dc voltage, which can be substituted for the 1-volt internal dc reference. The recorder will operate properly over a 3:1 reference-voltage

range (0.5 to 1.5 volts). If this reference voltage is derived from the source of energy in the system under test, variations of up to 3:1 in the source output can be eliminated from the recording.

Detector: Quasi-rms; within 0.25 db of rms for multiple sine waves, square waves, or noise. Detector operating level is 1 volt.

Chart Paper: 4-inch recording width on 5-inch paper. Charts have 8 major divisions, 40 total divisions on vertical scale, except 1521-9427, which has 80 total divisions, and 1521-9466, which has 50.

Accessories Supplied: 40-db potentiometer, 2 pens, 2-ounce bottle of red ink, 2-ounce bottle of green ink, bottle of potentiometer cleaner, 1 roll of 1521-9428 paper, droppers for filling pens, CAP-22 Power Cord, spare fuses, adaptor cable for connection to sound-measuring equipment and other devices having telephone jacks.

Accessories Available: Potentiometers, charts, ink, slow-speed motors, drive and link units, as listed in price table.

Power Requirements: 105 to 125 (or 210 to 250) volts, 60 cps, 35 watts. 50-cycle models are available; see price list below.

Cabinet: Rack-bench.

Dimensions: Bench model -- width 19, height 9, depth 13 1/2 inches (485 by 230 by 350 mm), over-all; rack model -- panel 19 by 8 3/4 inches (485 by 225 mm), depth behind panel 11 1/4 inches (290 mm).

Net Weight: 50 pounds (23 kg).

Shipping Weight: 64 pounds (29 kg).

U.S. Patent No.: 2,581,133.

General Radio Experimenter Reference: Volume 33, No. 6, June 1959

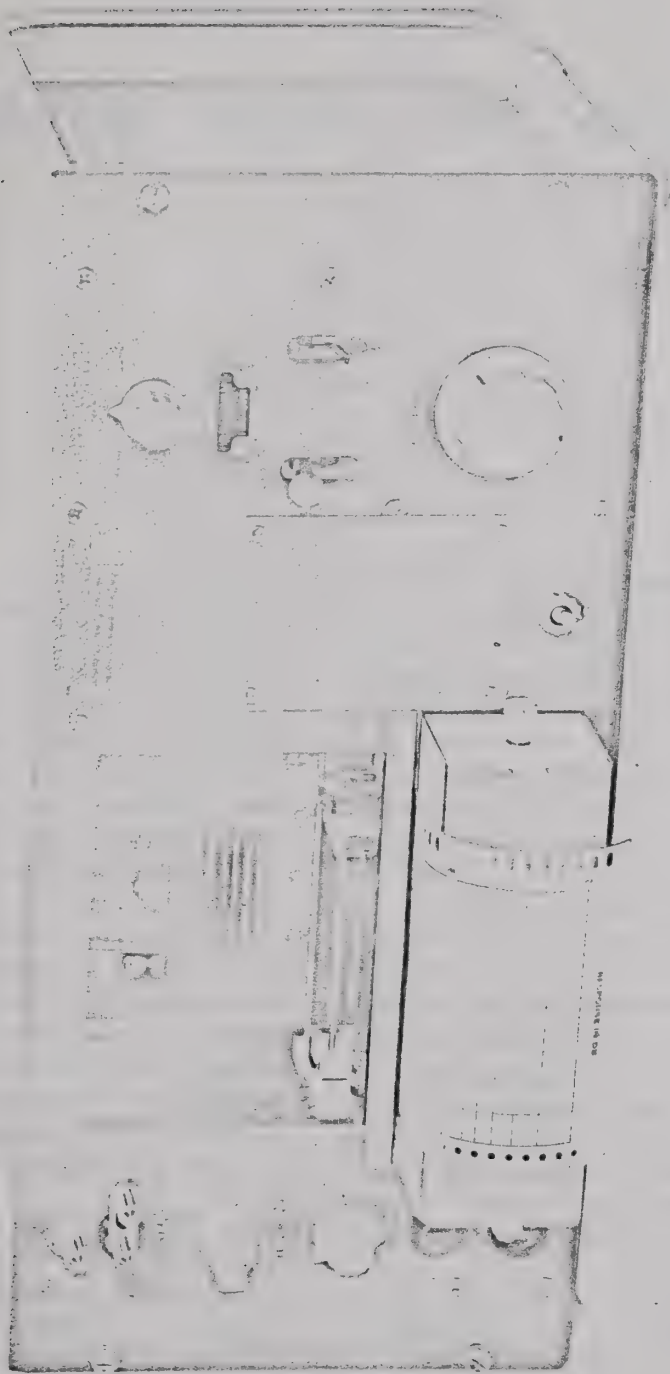


Figure 1.1. Type 1521-A Graphic Level Recorder.

TYPE 1521-A

GRAPHIC LEVEL RECORDER

Section 1

INTRODUCTION

E. The Type 1521-A Graphic Level Recorder (Figure 1.1) produces a permanent ink record of ac voltages, at frequencies from 20 cps to 20 kc, which is proportional to the logarithm of the input level, and hence linear in decibels, when the recorder is set up to drive the external oscillator, it automatically plots frequency, yielding a permanent record with minimum effort. The translucent paper permits one recording over another for comparison. The width is four inches.

Writing speed in conjunction with a wide range of signal levels from the outputs of various electroacoustic devices. Writing speed is constant for most reverberation-time measurements. The Type 1521-A can also be used as a dc recorder with an input-voltage range of 0 to 0.8 volt.

BRIEF DESCRIPTION. (See Figure 1.2.) The recorder is a servo-type recorder. The input signal is applied through an input-step attenuator to a potentiometer which is automatically positioned to maintain a constant ac signal at the wiper arm output. This signal is amplified and then rectified by a quasi-square-wave detector (refer to paragraph 4.3). The detector's output is compared with a 1-volt reference, and the error (error) voltage is amplified by a dc amplifier to produce a push-pull output current from the dc amplifier.

The amplifier passes through the drive coil, which is suspended in a magnetic field. The interaction between the coil current and the magnetic field moves the wiper arm to reduce the error voltage to zero (null condition), and also positions the pen mounted on the coil assembly. Since potentiometer output is a constant 1 mv at null, the attenuation of the input potentiometer is directly proportional to the level of the input signal. By suitable shaping of the potentiometer, a scale linear in db is achieved.

A feedback voltage, proportional to velocity, is subtracted from the error signal at the input to the dc amplifier. This voltage provides damping so that the drive coil will not oscillate, and varies the servo bandwidth and maximum writing speed.

The moving drive coil, then, responds to changes in the input level of a voltage applied to the recorder, and a pen fastened to the coil will trace out these changes on paper. For instance, if the input level increases by 10 db, the drive coil (along with the pen) moves the potentiometer wiper arm to restore the voltage

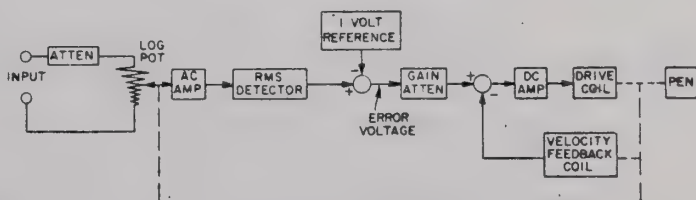


Figure 1.2. Block Diagram of Recorder.

a to about 1 mv. Since the potentiometer is e, the wiper arm moves downscale 10 db, in-level change of 10 db directly on the chart

Type 1521-A responds to the rms level of the m, and is less influenced by the waveshape ut signal than it would be with a peak- or sponse detector. The rms response is particu in noise measurements, where peak response se large errors in measurement.

used as a level recorder, the Type 1521-A ut impedance of 10,000 ohms. This impedance eared, at a sacrifice of sensitivity, by the a series resistor at the input.

a the recorder is used as a dc recorder, the er is bypassed and a linear potentiometer is input impedance of the dc recorder is 1000

NG SPEED. The maximum writing speed (pen velocity) is 20 in./sec for 0.1 inch over-e corresponding servo bandwidth for small-

amplitude variations is from dc to 10 cps. This band-width determines the ability of the recorder to follow changes in input level, and is not related to the frequency of the ac input signals. With a fast writing speed, the pen should follow any level variations normally encountered in level recording. Such fast speed can, however, present too much information, as, for instance, in a loudspeaker frequency response curve recorded in a small reverberant room. Filtering can be added to smooth the rapid level fluctuations to obtain an averaged response of the loudspeaker. This filtering is accomplished by reduction of the servo bandwidth and maximum writing speed.

1.4 PAPER SPEED. The paper is driven by a synchronous motor, at speeds of 2.5, 7.5, 25, or 75 in./min. (An alternate motor is available for speeds from 2.5 to 75 in./hr). The direction of paper drive can be reversed.

1.5 ACCESSORIES. The following tables list the accessories supplied with the recorder and those available from General Radio.

TABLE 1.1
ACCESSORIES SUPPLIED

Figure 1.3 Ref.	Accessory	Quantity	Part Number
1	pens	2	1521-3490
2	cleaning wires	10	
3	pen caps	2	
4	ink (2-oz bottle) red	1	1521-4090
	ink (2-oz bottle) green	1	1521-4091
5	eyedroppers	2	1521-4190
6	power cord	1	CAP-22
7	40-db logarithmic pot.	1	1521-P2
8	recording paper	1 roll	1521-9428
9	fuses (0.5 amp for 115V model) (0.25 amp for 230V model)	2	5330-1000 or 5330-0700
10	patch cord	1	1560-9695
11	potentiometer cleaner and lubricant (2-oz bottle)	1	1521-4200

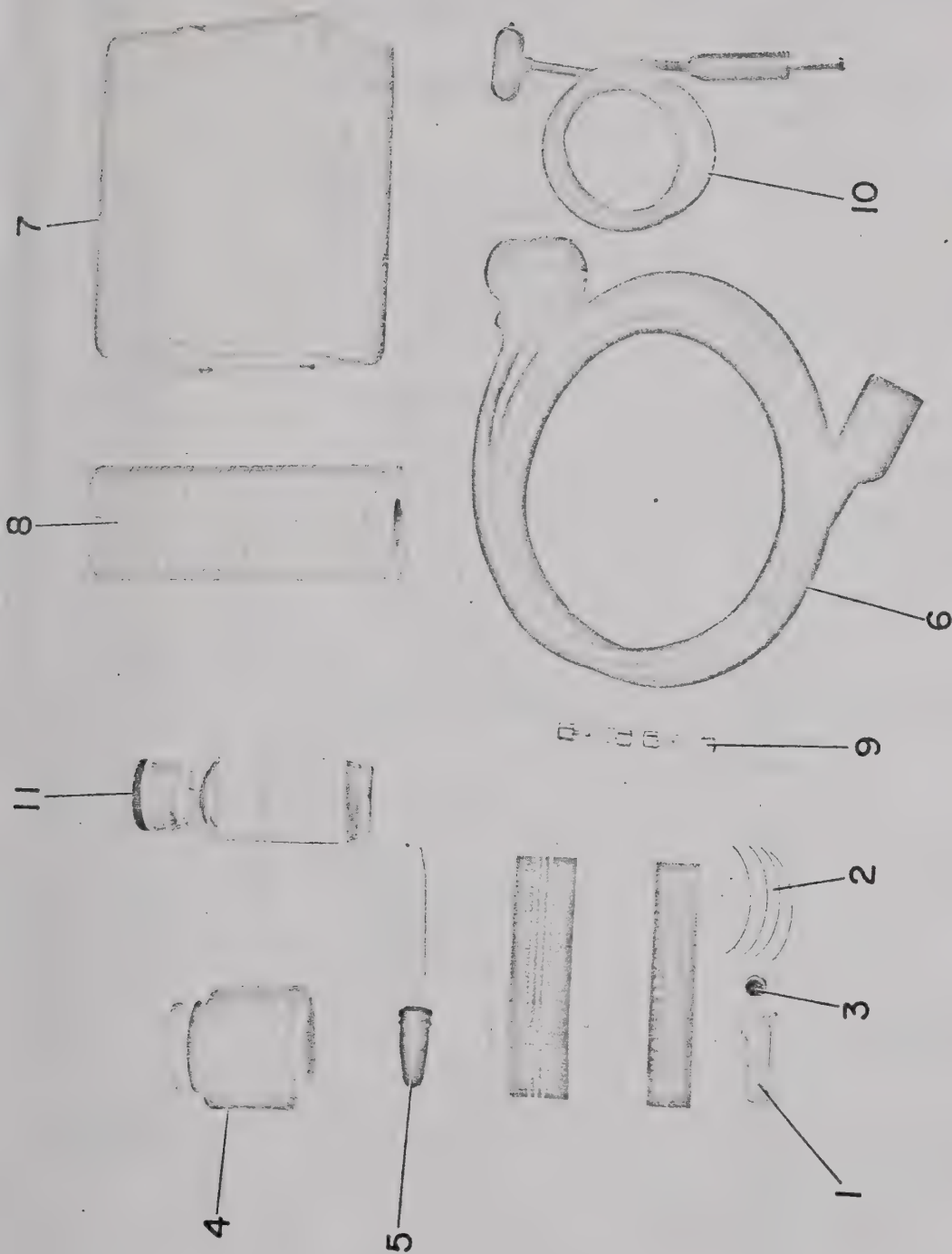


Figure 1.3. Accessories Supplied (for Legend See Table 1.1).

TABLE 1.2
ACCESSORIES AVAILABLE

Part No.	Item	Use
1521-P1	20-db logarithmic pot.	Recording 20-db range of input voltage level.
1521-P3	80-db logarithmic pot.	Recording 80-db range of input voltage level.
1521-P4	linear pot.	Recording dc.
1521-4092	ink (16-oz bottle) red.	
1521-4093	ink (16-oz bottle) green.	
1521-P20	slow-speed motor (60 cps).	Chart speeds from 2.5 to 75 in./hr.
1521-P22	slow-speed motor (50-cps).	Chart speeds from 2.5 to 75 in./hr, from 50-cps power.
1521-P10B	drive unit (15, Fig. 2.3).	Provides coupling to link unit on external instrument. Combination of drive unit and link unit synchronizes external frequency dial to special recording paper listed below.
1521-P15	link unit (1, Fig. 2.3) (complete with chain).	For coupling to Type 1304-B Beat-Frequency Audio Generator and Type 1554-A Sound and Vibration Analyzer.
1521-P16	sprocket kit for -P15 link unit.	Provides choice of scale factors (refer to General Radio Catalog).
1521-P12	link unit (complete with chain).	For coupling to Type 760 Sound Analyzer.
1521-9427	chart paper (Fig. 1.4).	Calibrated 20 cps to 20 kc, logarithmic, 9 inches, repeating every 13 1/2 inches; for use with Type 1304-B Beat-Frequency Audio Generator.
1521-9429	chart paper.	Calibrated 25 to 7500 cps in 1/3-decade segments 2 1/4 inches long, for use with Type 760-B Sound Analyzer.
1521-9463	chart paper (Fig. 1.5).	Calibrated 25 to 25,000 cps, repeating every 21 inches, for use with Type 1554-A and 1564-A Sound and Vibration Analyzer.

TYPE 1521-A GRAPHIC LEVEL RECORDER

TABLE 1.2 - ACCESSORIES (Cont)

Part No.	Item	Use
1521-9465	chart paper.	Calibrated 0 to 50 kc, linear, 10 inches, repeating every 16 inches; for use with Type 1900-A Wave Analyzer.
1521-9464	chart paper.	Calibrated 0 to 10 kc, linear, repeating every 20 inches; for use with Type 1900-A Wave Analyzer.
1521-9493	chart paper.	Calibrated 2.5 to 25 (normalized decades) for use with Type 1564-A Sound and Vibration Analyzer, 7½ inches per decade, repeating every 9 inches.
1521-9428	chart paper.	Linear time base, 1 division = ¼ inch; for ac or dc records as a function of time.
1521-9466	chart paper.	Linear time base, 1 division = 5/8 inch; 10 major divisions, 50 total divisions. For use with Types 1134-A and 1136-A Digital-to-Analog Converters.

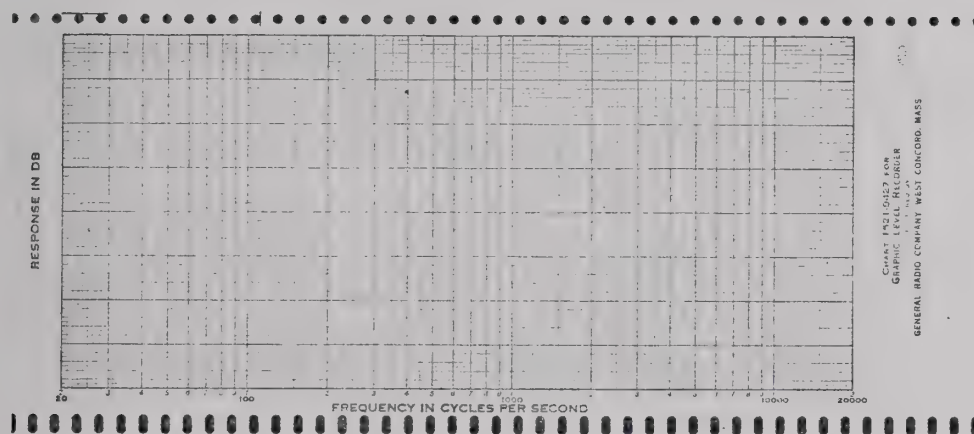


Figure 1.4. Type 1521-9427 Chart Paper.

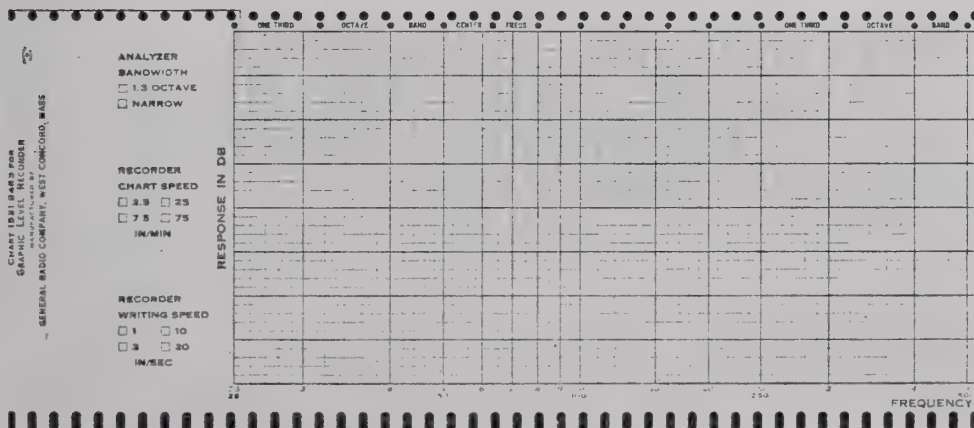


Figure 1.5. Type 1521-9463 Chart Paper.

Section 2

INSTALLATION

ERAL.

OUNTING. The recorder should be mounted so reasonably level during operation. Two models of instrument are available: The Type 1521-AM for counting, and the Type 1521-AR for relay-rack mounting. The bench model can be rack-mounted if the feet are removed.

The use of transistors in the recorder makes it less sensitive to a consideration than it would be with vacuum tubes, but operation at high temperatures (above 100°C) is not recommended.

PAPER LOADING (Refer to Figure 2.1). To load the recorder with paper, proceed as follows:

1. Remove the two thumb screws (1, Figure 2.1), and the paper cover (2).

2. Pull out the spring-loaded paper knob (3), and in-

sert the roll of paper, with the loose end at the bottom, facing in toward the recorder.

c. Grasp the pen (4) and swing it up, away from the drum.

d. Guide the paper under and around the drum, using the left hand.

e. Set the gear-shift lever to N and turn the MANUAL SET knob clockwise with the right hand. Let the pins pull the paper only as far as the pen.

f. Attach the paper cover (2) and fasten it with the two thumbscrews.

g. Move the paper along by turning the MANUAL SET knob, guiding the edge under the pen (4) and rollers (5). The paper should go over the top of the paper cover and under the tear gate (6). It may be necessary to push down slightly on the paper cover.

h. To tear the paper, lift it from one edge against the tear gate. The paper cover provides a convenient writing surface.

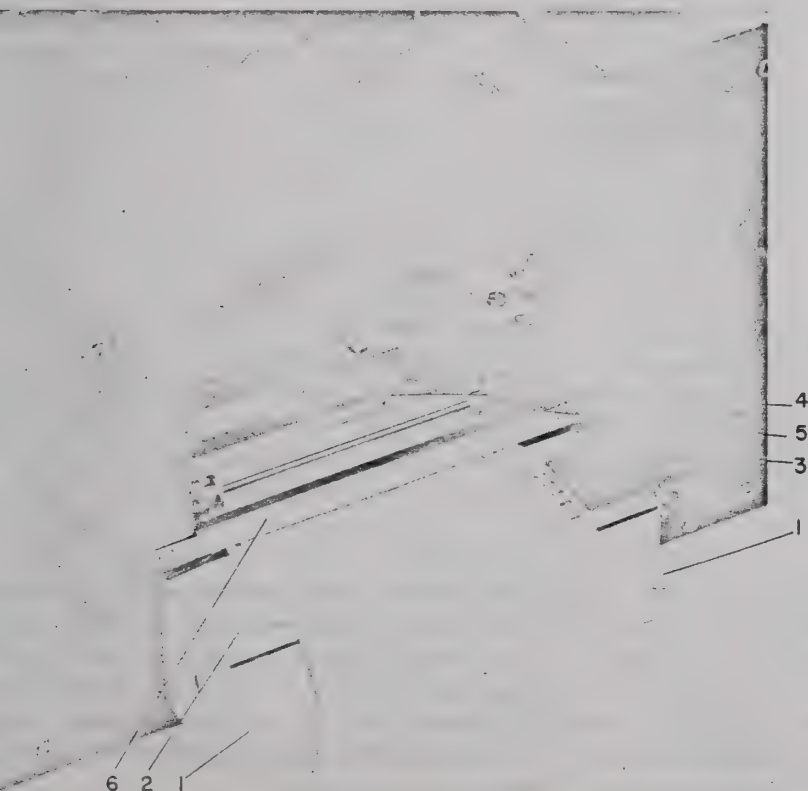


Figure 2.1. Front Oblique View of Recorder.

1. Thumb Screws
2. Paper Cover
3. Paper Knob
4. Pen
5. Rollers
6. Tear Gate
7. Thumb Screws
8. Potentiometer Input Plug
9. Potentiometer Selector Switch

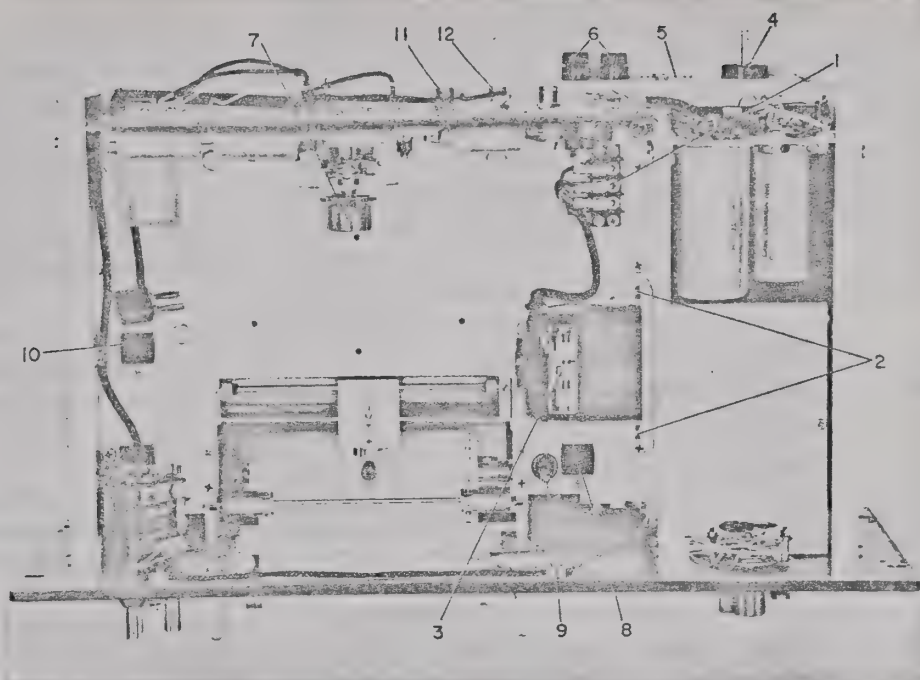
TYPE 1521-A GRAPHIC LEVEL RECORDER

Top View of Recorder.

Terminal Strip
Mounting Screws

Connector
Nameplate

Potentiometer Selector Switch
Potentiometer Connector
Motor Switch
Potentiometer Connector
DOT Adjustment
Adjustment



ING PEN. To fill the pen, first remove the cap by pulling it gently from its clamping. Remove the cap, and, using the eyedropper, fill the pen no more than 4/5 full with the ink supplied. Replace the cap, pivot the pen holder up, and push the pen assembly back into place, with its point held in the front mounting fork.

CAUTION

Only the type of ink supplied by Gen-Radio Company. Other inks may dry, clogging the pen. When replacing the cap, be sure that the air hole is not clogged. The ink does not flow through the capillary to the point, the air may be removed by the eyedropper. Leave the pen up (pointing from the paper) until making a recording.

CHANGING POTENTIOMETER. A 40-db potentiometer is supplied installed in the recorder. Two other potentiometers and a linear potentiometer are available. Select a logarithmic potentiometer on the basis of the dynamic range of input levels to be recorded (see Table 2.1), and select the linear unit for

potentiometers can be installed without removing the instrument from its case. When changing potentiometers, remove the unit to be replaced as follows: Disconnect the input plug (8, Figure 2.1) and loosen the thumb screws (7) enough to free the potentiometer. Remove the potentiometer by withdrawing it from the opening in the front panel. On linear potenti-

ometers, a Jones connector on the left-hand side must be unplugged before the potentiometer can be removed.

To install a potentiometer, proceed as follows:

a. Set the potentiometer selector switch (9) to the position corresponding to the potentiometer being installed. The pins at the rear of the potentiometer case are guide pins that clear the selector switch only if it is set properly.

b. Move the input plug and cable out of the way, and insert the potentiometer through the panel opening. Two locating pins on the bottom of the potentiometer and mating holes in the shelf assure proper seating of the unit. When the potentiometer is in place (see Figure 2.1), tighten the thumb screws (7) and connect the input plug (8). With a linear potentiometer, connect the Jones plug in the mating socket (10, Figure 2.2).

TABLE 2.1

POTENTIOMETER INPUT-LEVEL RANGES
Input Voltage Range Recorded on 4-in. Paper

Attenuator Setting db	80 db Pot.	40 db Pot.	20 db Pot.
0	1mv - 10v	1 - 100mv	1 - 10mv
10	3mv - 30v	3 - 300mv	3 - 30mv
20	10mv - 100v	10mv - 1v	10 - 100mv
30	30mv - 100v*	30mv - 3v	30 - 300mv
40	100mv - 100v*	100mv - 10v	100mv - 1v
50	300mv - 100v*	300mv - 30v	300mv - 3v
60	1 - 100v*	1 - 100v	1 - 10v

*Limited by attenuator power rating.

GENERAL RADIO COMPANY

MOTOR INSTALLATION. A standard-speed motor is supplied installed in the recorder. A 5-rpm motor is also available. To change proceed as follows:

1. Remove the potentiometer, as described in paragraph 4.

2. Remove the four black thumb screws at the front and the two at the rear of the instrument, and remove the recorder out from its case.

3. Loosen the three screws holding the motor leads to the terminal strip (1, Figure 2.2), and slip the lugs out.

4. Remove the two motor mounting screws and lock washers (2).

5. Remove the motor (3).

6. Install the new motor, positioning the mounting bracket so that the bearing and screws mate with the proper holes.

7. Fasten the motor using the screws and lock washers removed in step d.

8. Loosen the three motor leads to the terminal strip and match with the color coding (R, B, G, for red, black, green) stamped on the shelf.

9. Replace the potentiometer as described in paragraph 4, slide the instrument back into its case, and tighten the six screws removed in step b.

POWER CORD. Connect the power cord to the plug connector at the rear of the recorder (4, Figure 2.1). A small nameplate (5) to the right of this connector indicates the voltage and frequency for which the recorder is wired. A good ground connection should be made by connecting the third conductor of the power cable to the ground terminal to prevent pickup.

The recorder, normally supplied wired for 115-volt ac, can be rewired for 230-volt use as shown on the wiring diagram.

CONNECTIONS TO AUXILIARY EQUIPMENT. A special INPUT connection is provided for the measurement of ac voltages with dc potentials above ground. High dc potentials should not be applied to the input terminals, in view of the 1-watt power resistors in the attenuator.

In the normal measurement where the low side of the signal is at ground potential, connect the grounding lead between the ground and black binding posts, and use the black posts as input connectors. If both input terminals have a dc potential above ground, remove the grounding link from the black binding post, and use the black posts as input connectors. Connect the other end of the ground of the circuit under test to the ground binding post. The ac impedance between the black binding post and chassis ground must be low to prevent hum. To check this, make all connections except that to the input terminal, short-circuit the red and black bind-

ing posts, turn the recorder on, and check that the pen moves off scale at the 0 db end of the potentiometer. It may be necessary to connect a capacitor between the black and ground binding posts to provide a low enough impedance for the pen to move off scale. If hum pickup is still such that a pronounced beat occurs with a 61-cps input, more capacitance should be added to lower the impedance.

The connections for a typical three-terminal ac measurement are shown in Figure 2.5.

The three-terminal INPUT is also useful for dc measurements, where both measurement points are above ground.

2.2 LEVEL-VS-FREQUENCY RECORDING.

2.2.1 GENERAL. The instrument is supplied set up for time-base measurements, using Type 1521-9428 linear chart paper. Several accessories are required to convert the instrument to a frequency-base level recorder.

2.2.2 DRIVE-UNIT INSTALLATION. The Type 1521-P10B Drive Unit consists of (1) gears and sprocket to couple the recorder to the external instrument, (2) a clutch to permit decoupling between the recorder drive and the sprocket, and (3) microswitches to turn the motor off at the two ends of the sweep. The Drive Unit may be installed permanently on the recorder, since the clutch can be used to disconnect the Drive Unit when not in use.

To install the Drive Unit, proceed as follows:

a. Remove the cover plate to the right of the front panel opening by removing the four phillips-head screws.

b. Connect the Drive Unit plug to the socket between the motor and the front panel of the recorder (8, Figure 2.2). Snap the switch (9) next to this socket toward the front of the recorder to connect the microswitches into the motor circuit.

c. Install the Drive Unit, using the screws removed in step a. Adjust the height of the Drive Unit so that the gears mesh with a slight amount of backlash.

2.2.3 INSTALLATION OF LINK UNIT ON TYPE 1304-B BEAT-FREQUENCY GENERATOR OR TYPE 1564-A SOUND AND VIBRATION ANALYZER. A Link Unit, including sprocket and chain, must be installed on the frequency dial of the driven instrument to couple it properly to the recorder. The Type 1521-P15 Link Unit (Figure 2.3) is designed to couple the recorder to the Type 1304-B Beat-Frequency Generator or the Type 1564-A Sound and Vibration Analyzer.

To install the Type 1521-P15 Link Unit, proceed as follows:

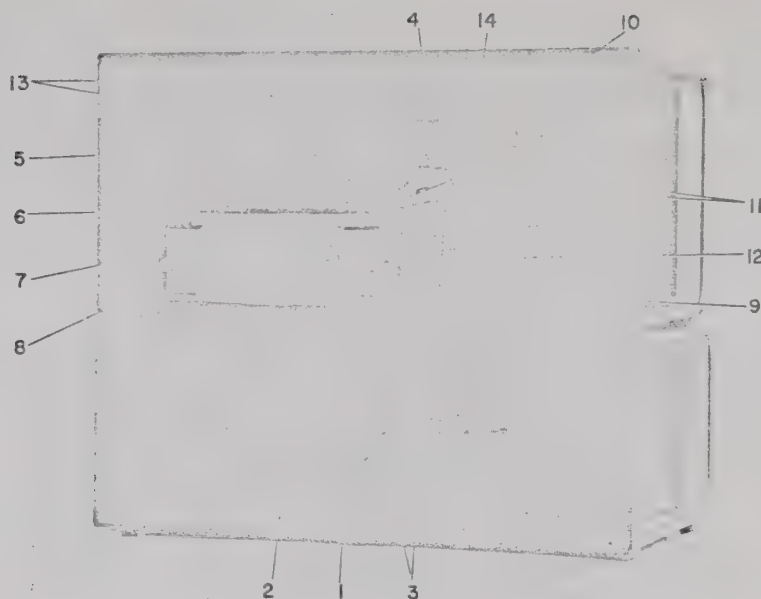
a. Place the Type 1304-B either above or below the recorder in a relay rack or on a bench (see Figure 2.3).

The Type 1564-A should always be placed above the recorder (see Figure 2.4).

TYPE 1521-A GRAPHIC LEVEL RECORDER

Figure 2.3. Recorder Attached to Type 1304-B Beat-Frequency Audio Generator.

Link Unit
Cam Holding Screw
Idle Sprockets
Microswitch Stops
INPUT ATTENUATION Control
WRITING SPEED Control
DAMPING Adjustment
CALibration Adjustment
POWER Switch
CHART DRIVE Switch
Chart Speed Controls
MANUAL SET Control
INPUT Terminals
Drive Unit Clutch
Paper Knob



Adjust the position of the Link Unit so that there is a slight amount of backlash when the sprocket is turned.

d. Slip the chain over the sprockets of the Drive and Link Units. (See Figures 2.3 and 2.4).

e. Tighten up any slack in the chain by first loosening the screw (2, Figure 2.3) and then swinging the idler sprocket (3) to take up the slack in the chain. Tighten the screw (2).

NOTE

On some models of the Type 1304-B Generator, the frequency dial can be rotated 360° . With these instruments it is desirable to remove the Drive Unit microswitches so that the frequency dial can sweep the whole 360° . To cut out the microswitches, snap the toggle switch (9, Figure 2.2) toward the rear of the instrument.

Figure 2.4 Recorder attached to Type 1564-A Sound and Vibration Analyzer.

Remove the two screws attaching the knob and assembly to the panel of the driven instrument, and remove the knob and plate. Using the screws removed in step b (but not the washers), mount the Link Unit in place of the knob.

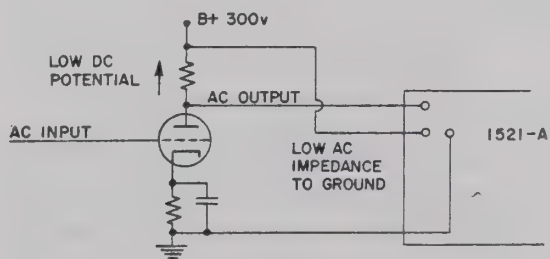


Figure 2.5 Connections for Three-Terminal AC Measurements.

GENERAL RADIO COMPANY

CHANGING SPROCKETS ON TYPE 1521-P15 LINK UNIT. A Type 1521-P16 Sprocket Kit is available for use with the Type 1521-P15 Link Unit. By changing sprockets, it is possible to change the length of the recording paper covered by a given angle of dial rotation (refer to paragraph 3.4.5). To change the sprock-

Loosen the setscrews and remove the knob.

Remove the sprocket.

Slide the new sprocket onto the shaft.

Replace the knob.

Make sure the pin on the shaft engages the key slot on the sprocket before the setscrews are tightened.

INSTALLATION OF LINK UNIT ON TYPE 760-B SOUND ANALYZER. The Type 1521-P12 Link Unit is designed to couple the Type 760-B Sound Analyzer (now obsolete) recorder. To install this unit, proceed as follows:
a. Set the frequency dial to an integral setting and note the frequency.

b. Remove one of the two screws holding the frequency pointer on the Type 760-B, and swing the pointer to the way of the dial.

c. Loosen the two setscrews holding the frequency pointer to its shaft, and remove the knob and dial assembly. Be careful not to move the shaft. If the shaft does turn,

the analyzer can be recalibrated with a 60-cps line source.

d. Install the Type 1521-P12 Link Unit on the shaft, and replace the pointer.

e. Set the dial frequency to that noted in step a, and tighten the setscrews.

f. Four rubber feet are supplied with the Link Unit to act as spacers between the analyzer and the recorder. Install these permanently on the bottom of the analyzer by means of the four wood screws supplied.

g. Place the analyzer above the recorder and attach the chain to the drive and link sprockets. Move the analyzer to take up chain slack.

h. Disconnect the microswitches on the recorder as described in paragraph 2.2.3 e, NOTE.

2.3 DC RECORDING. To prepare the recorder for dc measurements, proceed as follows:

a. Install the dc linear potentiometer (refer to paragraph 2.1.4).

b. Set the INPUT ATTENUATOR switch to 0 db for maximum sensitivity. Refer to paragraph 3.5 for adjustment of DAMPING control.

Section 3

OPERATING PROCEDURE

CONTROLS. Tables 3.1, 3.2, and 3.3 list the functions of all controls on the recorder. Study this list to gain an over-all familiarity with the instrument before attempting to operate it.

GENERAL OPERATION.

PLACING RECORDER IN OPERATION. (Refer to Section 2 for installation instructions, including setting of input levels with various potentiometers.) Lift the pen off the paper and set the WRITING SPEED control to a slow position (1 or 3 in./sec). This will protect the coil assembly from banging on the stops when it is turned on. Now the POWER switch may be turned ON.

2 APPLYING SIGNAL TO INPUT. Apply the signal to be recorded to the INPUT terminals using a shielded cable. (Refer to paragraph 2.1.7.)

The ranges of input levels that can be recorded are given in Table 2.1. Because of power ratings of the attenuator resistors, the input level should not exceed 100 db. The dynamic range of input levels to be recorded should be considered in the selection of the potentiometer.

ter. Choose the lowest-range potentiometer that will handle the level changes and still keep the pen away from the stops. This will ensure the greatest precision and accuracy of the recorded level changes.

3.2.3 POSITIONING PEN AND READING CHART.

3.2.3.1 Absolute Level (Millivolts). Set the INPUT ATTENUATOR so that pen is in the desired position on the paper, ensuring that the pen will stay on the paper during the whole recording. When an auxiliary instrument is to be driven, first run through a "dry recording" with the pen off the paper, to check the range.

If the 0 db level has been calibrated to read 1 mv (refer to paragraph 3.2.7), the recorded level will be the sum of the INPUT ATTENUATOR reading and the chart reading (as noted on the front of the potentiometer), in decibels above 1 mv. For example, if, with the INPUT ATTENUATOR set at 40, the pen recorded a level of 3 db, the recorded level would be 43 db above 1 mv.

The level can be converted from db above 1 mv to millivolts by use of db-to-voltage conversion tables such as those found in the General Radio Catalog.

Relative Level (in db with respect to arbitrary reference level). Many types of measurement do not require a reference level in volts, and it is often satisfactory to use an arbitrary reference as 0 db and to compare readings with this level.

The 0 db reference level can be positioned on the chart by means of the INPUT ATTENUATOR and CAL controls. If the CAL control is used, 0 db on the chart no longer represents 1 mv. (Refer to paragraph 3.2.3 for readjustment.)

When a recording is made with respect to an arbitrary

reference, the chart reading is simply compared with this reference level. If the INPUT ATTENUATOR setting is then changed, the change in input attenuation must be added to the chart reading.

3.2.4 WRITING SPEED. The WRITING SPEED control adjusts the maximum pen velocity and the maximum bandwidth of the servo system. The fastest writing speed (20 in./sec) is generally the most desirable, where the servo bandwidth is maximum (10 cps). The 10-in./sec speed has about half the servo bandwidth of the 20-in./sec speed, and is the fastest speed possible without over-

TABLE 3.1
CONTROLS ON THE RECORDER

Fig. Ref	Name	Type	Function
5, Fig. 2.3	INPUT ATTENUATION	7-pos rotary switch	Selects attenuation applied to input signal. Setting is added to db reading on paper to give level of input above 1 mv when 0 db reference is calibrated to 1 mv.
6	WRITING SPEED	4-pos rotary switch	Controls maximum velocity of pen and servo bandwidth.
7	DAMPING	Thumb adjustment	Adjusts overshoot on fastest writing speed (20 in./sec). Turn clockwise to increase damping.
8	CAL	Thumb adjustment	Sets voltage level of 0 db reference. Nominally set for 1 mv.
9	POWER	Toggle switch	Power switch.
10	CHART DRIVE	3-pos rotary switch	Off-forward-reverse control for chart-paper drive mechanism.
11	Paper speed	Levers (2)	Left-hand lever setting times right-hand (multiplier) setting equals number of divisions per minute on 1521-9428 linear paper.* N (neutral) position permits operation by MANUAL SET control.
12	MANUAL SET	Continuous rotary control	Manual paper drive control with lever in N (neutral).
9, Fig. 2.1	Potentiometer selector	4-pos rotary switch	Potentiometer circuit selector.
9, Fig. 2.2	External motor switch	Toggle switch	In forward position, connects microswitches to motor.
11, Fig. 2.2	OVERSHOOT	Screwdriver adjustment	Sets overshoot for upscale direction only (increased signal transient).
12, Fig. 2.2	CREEP	Screwdriver adjustment	Removes slow creep in transients.

* or div/hr, depending on motor used.

TABLE 3.2
CONNECTORS ON RECORDER

Fig. Ref	Name	Type	Function
13, Fig. 2.3	INPUT	Jack-top binding posts (3)	Connection for grounded (red and grounded black) or ungrounded (red and black) input.
8, Fig. 2.2	DRIVE UNIT	Jones socket	Connection to Drive Unit.
10, Fig. 2.2	DC POT	Jones socket	Connection to linear potentiometer.
8, Fig. 2.1	Potentiometer input plug	Type 274 Double Plug and Cable	Connection to potentiometer.

TABLE 3.3
CONTROLS ON RECORDER ACCESSORIES

Fig. Ref	Name	Accessory	Function
14, Fig. 2.3	Drive Unit Clutch	1521-P10B Drive Unit	Decoupling between recorder chart drive and auxiliary instrument. Auxiliary equipment decoupled in idle position.
2, Fig. 2.3	Idler Gear Adjustment	1521-P14 Link Unit	Takeup for chain slack.
	Zero (thumbset control)	DC Linear Potentiometer	Adjusts zero input level to any position on recording paper.
	Sensitivity (screwdriver control)	DC Linear Potentiometer	Adjusts full-scale dc sensitivity to 0.8 volt.

ever, even at 20 in./sec overshoot is usual; refer to paragraph 3.2.5.) The slower in./sec and 1 in./sec are used where un- or fluctuations are to be filtered from the

ING. The overshoot on the fastest speed is normally set to one chart division on 9428 and -9463, and -9429 Paper, two divisions on -9427 Paper, for step changes at the input. preferred writing speed, since changes in are normally instantaneous. Thus the overshoot, with optimum response to level changes. not can be varied by means of the DAMPING by turning this thumbset adjustment clockwise in damping, thus decreasing the amount of overshoot. If the overshoot is not symmetrical, refer to 3.2.

serve the overshoot, apply a constant-level input, turn the chart drive on, and change the INPUT ATTENUATOR setting by 10 db.

NOTE

If the DAMPING setting is decreased below a certain point, oscillation will occur. Correct by turning the DAMPING adjustment clockwise.

RECORDING. Move the gear shift levers to the FWD and turn the motor on by turning the CHART DRIVE switch to FWD. The numbers engraved on the gear shift levers indicate speed in terms of Type 9428 (linear) Chart Paper divisions per minute (or, if a low-speed motor is installed, in divisions per second). The speeds possible are 10, 30, 100, and 300 divisions per minute (hour), corresponding to 2.5, 7.5, and 75 inches per minute (hour). It is not necessary to turn off the motor to stop the chart drive; simply move the gear shift lever to N (neutral). However, do not

shift the left gear-shift lever while the chart is moving.

When the paper is moving, place the pen in its writing position and start recording.

CAUTION

With the pen on paper and moving, the recording paper must be moving, or the pen will clog with paper.

3.2.7 CALIBRATING 0-DB LEVEL TO 1 MV. In order to calibrate the recorder so that the 0-db settings of INPUT ATTENUATOR switch and pen both correspond to 1 mv, proceed as follows:

a. Connect a stable oscillator to the input of the recorder. Set this oscillator to a frequency well within the pass band of the recorder (e.g., 1 kc). The 60-cps line will do if it is attenuated externally. (Refer to Table 2.1.)

b. Monitor this input voltage with an ac rms voltmeter. (Many oscillators, such as the Type 1304-B Beat-Frequency Generator, include a voltmeter for monitoring the output.) The accuracy of the voltmeter used will limit the calibration accuracy. A voltmeter accuracy of five percent corresponds to a calibration accuracy of 0.5 db.

c. Adjust the oscillator output to produce a convenient voltmeter reading.

d. Noting which line on the chart paper corresponds to 0 db, use the INPUT ATTENUATION and CAL controls to set the pen in accordance with the voltmeter reading. For instance, if the voltmeter reads 1 volt (60 db above 1 mv), set the INPUT ATTENUATION control to 40 db and, using the CAL control, position the pen on the 20-db line on the paper.

3.3 LEVEL-VS-TIME RECORDING. Recordings of level vs time can be made on the Type CTP-505 Chart Paper supplied with the instrument. To calibrate the time scale, simply take the reciprocal of the paper speed. Thus, with a chart speed of 300 divisions per

TYPE 1521-A GRAPHIC LEVEL RECORDER

TABLE 3.4

MAXIMUM RECOMMENDED SWEEP SPEEDS FOR THE
TYPE 760-B SOUND ANALYZER AND TYPE 1554-A SOUND AND VIBRATION ANALYZER

Recommended Max Sweep Speed (Div/Min)

Frequency Band	20-db Pot.			40-db Pot.			80-db Pot.		
	760	1564 & 1554 N.B.	1564 & 1554 1/3 OCT.	760	1564 & 1554 N.B.	1564 & 1554 1/3 OCT.	760	1564 & 1554 N.B.	1564 & 1554 1/3 OCT.
25 - 250 cps	10	30	30	10	30	30	10	30	30
	10			10			10		
250 cps - 2.5 kc	30	100	100	30	100	100	30	100	100
	30			30			100		
2.5 - 25 kc	30	100	100	30	100	100	100	100	100

N.B. indicates NARROW BAND

each division equals 1/300 minute, or 1/5 sec-

is advisable to use a fast writing speed with per speeds and a slow writing speed with slow speeds, so that the recording can be read easily. tance, a sound-level measurement versus time how very little if the fastest writing speed were th the slowest paper speed.

VEL-VS-FREQUENCY RECORDING.

GENERAL. After the necessary Drive and Link ive been installed (refer to paragraphs 2.2.2 and he frequency dial of the driven instrument must hronized with the appropriate recording paper. o paragraph 1.5.) The synchronization procedure llows:

row the Drive Unit clutch out (idle position). t the right-hand chart-speed lever to N, and turn UAL SET control to set the chart paper to the low-frequency limit. t the right-hand chart-speed lever to x10 or x1. urn the oscillator dial to the desired low-frequen- (corresponding to the recorder paper). row the clutch into the NORMAL DRIVE posi- instruments with dial stops (the slip clutch on e 1521-P10B protects the dial stop) or into the .IP position for instruments without dial stops : large driving torques are required.

CAUTION

he NON-SLIP position should not be used ith external instruments that have dial ops, since, in this case, no protection provided.

f. Throw the external motor switch (9, Figure 2.2) toward the front panel to connect the microswitches to the motor.

g. Position the reverse limit microswitch stops, (4, Figure 2.3) so that it just turns off the recorder motor in the REV drive position.

h. Set the CHART DRIVE switch to FWD and sweep through the desired frequency range. Set the forward limit switch to turn the recorder motor off at the desired high-frequency limit.

i. Sweep back and forth, checking frequency limits at the paper speed to be used. Also check the chart and dial frequencies against each other.

NOTE

The Type 760-A Sound Analyzer, the Type 1564-A Sound and Vibration Analyzer, and some models of the Type 1304-B Beat-Frequency Generator have frequency dials that can be swept through 360°. Turning the external motor switch toward the rear of the instrument will disconnect the limit switches for 360-degree rotation.

The equipment is now ready for recording. With the pen up, check that it will stay within the useful re- cording range during the frequency sweep. If necessary, change the INPUT ATTENUATOR setting or install a wider-range potentiometer.

When making the first recording, be careful not to sweep the auxiliary instrument too fast or there will be errors in the recording. If slow writing speeds are to be used to filter noise, it is advisable to use a slow paper speed as well. (Remember that slow writing speeds limit the ability of the recorder to respond to level changes.)

ERATION WITH TYPE 1304-B BEAT-FRE-GENERATOR. The Type 1304-B Beat-Fre-nerator is an excellent signal source with est response of various systems. The output e 1304-B is fed to the system under test, and output is recorded. The voltage variations of 304-B are less than ± 0.25 db between 20 cps

later models of the Type 1304-B, where the dial can be swept 360° , production tests for response can be made with no lost time. The ft running, and each component is plugged in- during the blank space of the Type 1304 dial.

PERATION WITH TYPES 1554-A and 1564-A ND VIBRATION ANALYZERS AND TYPE D ANALYZER. Analysis of noise or of elec- als versus frequency can be made quite con- by means of the Type 1564-A Sound and Vib- lyzer or the Type 760 Sound Analyzer (now or Type 1554-A Sound and Vibration Ana- plete) connected to the recorder. The signal yzed is connected to the input of the anal- analyzer output coupled to the recorder.

eme care is necessary when the analyzer is pecially at lower frequencies. A fast sweep errors in the recorded amplitude, center fre- the filter, and effective bandwidth of the fil-

3.4 gives the maximum recommended sweep the Types 760, 1564, and 1554 Sound Ana- ne sweep speeds in Table 3.4 give an error de less than 2% of full scale (0.8 db for the ntiometer) with one exception. The lowest ie Type 760-B contributes a magnitude error at 25 cps when a 20-db potentiometer is used the analyzer is swept at the lowest possible d. (The slow-speed motor would reduce the it may not be convenient to change motors.) p speeds in Table 3.4 give an error in mag- s than 2% of full scale (0.8 db for the 40- ometer) with one exception. The lowest band e 760-B contributes a magnitude error of 0.8 cps when a 20-db potentiometer is used and analyzer is swept at the lowest possible paper ie slow-speed motor would reduce the error, not be convenient to change motors.)

Type 760-B can be swept 360° , and a con- alysis can therefore be made from 25 cps to rting at 25 cps, the recording is made in the decade to 75 cps. During the white range of paper after 75 cps, the next range button on er is pressed. This is repeated on succes- s until the entire frequency range is covered.

The Type 1564-A can be swept through 360° and, in addition, the range switching is accomplished auto- matically as the recorder sweeps the analyzer through the blank portion of the dial.

3.4.4 OPERATION WITH TYPE 1900-A WAVE ANAL- YZER. The Type 1900-A Wave Analyzer, when used with the Type 1521-A Recorder (Figure 3.1), provides a system for the automatic recording of spectra in the frequency range of 20 to 50,000 cps. Unlike the sound analyzers, the wave analyzer offers a choice of three fixed bandwidths: 3, 10, or 50 cps. For a detailed de- scription of this analyzer and its use with the recorder, refer to the General Radio Catalog and the Operating Instructions for the Type 1900-A.

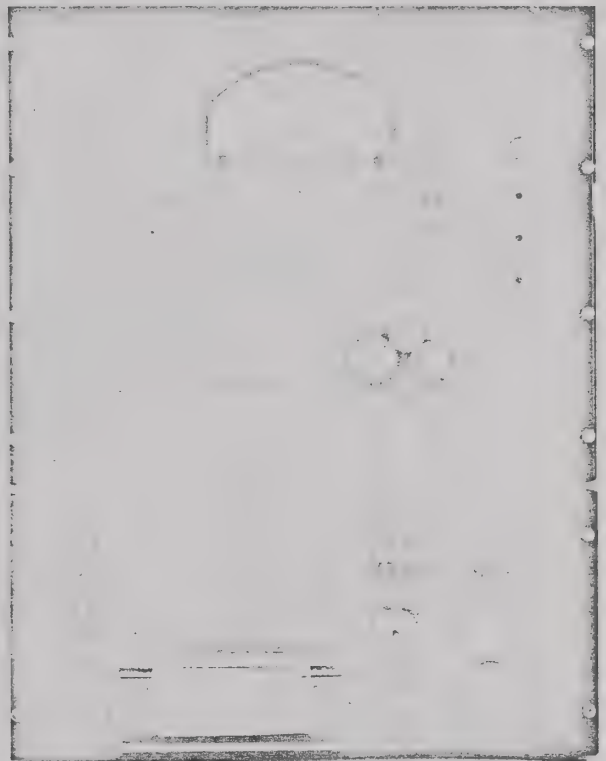


Figure 3.1. Recorder Attached to Type 1900-A Wave Analyzer.

3.4.5 CHOICE OF SCALE FACTORS FOR RECORD- ING LEVEL VS FREQUENCY. Many different stan- dards for the length of a frequency decade on a log- arithmic chart and for the scale factor are now in use. The scale factor is the product of the db per inch on the vertical scale and the inches per decade of fre- quency on the horizontal scale, expressed in db per decade. The Type 1521-P15 Link Unit provides one of the standards commonly accepted in the United. States. The Type 1521-P16 Sprocket Kit, for use with the Type 1521-P15, covers most of the current stan-

TYPE 1521-A GRAPHIC LEVEL RECORDER

lists some of these standards with scale factors obtained with the varied in the Type 1521-P16 Sprocket 24-tooth sprocket supplied with the available from General Radio. All rs should be ordered from Gubelman 0 E, Hirnney St., Neward, N. J.

ING. When the Type 1521-P4 Linear installed and the DAMPING control is divisions of overshoot, the waveforms signals can be recorded. (Refer to or bandwidth limitations.) The proce- g the DAMPING control is as follows:

- Using the zero thumb control on the front of the dc potentiometer, set the zero input position of the pen about five divisions from the left side of the chart.
- Set the WRITING SPEED control to 20 in./sec and the INPUT ATTENUATOR switch to 0.
- Apply about 0.5 volt dc to the INPUT connectors (e.g., a 1.5-volt dry cell with 2000 ohms in series).
- Turn the chart drive on.
- Switch the INPUT ATTENUATOR back and forth from 0 to 10 db.
- Adjust the DAMPING control so that the overshoot is two divisions on the Type 1521-9428 Paper. (Refer to paragraph 4.10 for a discussion of overshoot and band- width.)

TABLE 3.5
INDUSTRY SCALE FACTORS

Industry Standard	Scale Factor db/decade	Decade Length (inches) for Type 1304 Oscillator	Sprocket (teeth)	Pot. (db)
Institute of High Fidelity Manufacturers	20	2.0	16	40
Proposed International Standard	25	2.5	20	40
Electronic Industries Assoc- iation (1521-P14)	30	3.0	24	40
Institute of High Fidelity Manufacturers	20	4.0	32	20
Hearing Aid Industry	45	4.5	36	40
Proposed International Standard	50	5.0	40	40
Proposed International Standard	50	5.0 (Type 1564)	16	40

Section 4

PRINCIPLES OF OPERATION

GENERAL. The general principle of operation is in paragraph 1.2. This section will describe component (refer to the block diagram, Figure 1.2) will discuss sources of measurement error, so user may understand the limitations of the instrument and thereby achieve accurate recordings.

INPUT CIRCUIT AND AC AMPLIFIER. The calibration input attenuator has a 60-db range, in six 10-db steps. The input impedance is 10,000 ohms for all attenuator settings. The 10,000-ohm potentiometer represents a compromise between the desire for high input impedance and the desire to minimize capacitive loading of the ac amplifier.

The ac amplifier comprises an emitter-follower stage, four stages of gain, and a phase-inverter stage to drive the detector. The high input impedance of the emitter follower minimizes its loading effect on the potentiometer. The amplifier gain is approximately 1000, and can be adjusted to exactly 1000, by means of a gain control, for measurement of absolute levels.

The four stages of gain are in two two-stage sections. In each section, a large amount of dc feedback stabilizes transistor operating points against temperature changes. There is also enough ac negative feedback to insure stability of calibration. A regulated power supply minimizes the effects of line-voltage variations.

The dynamic range of recorded signals depends upon the potentiometer, since ac voltage levels within the amplifier are constant at null. (Refer to paragraph 1.2.) However, to allow faithful reproduction of input signals with a peak-to-rms ratio of 5 to 1, the ac amplifier has a 15-db dynamic range.

4.3 DETECTOR. A full-wave detector is used in the recorder, minimizing the effects of ripple for low-frequency inputs. Its quasi-rms response¹ closely approximates true rms for commonly encountered waveforms. The output is within 0.25 db of true rms for sine waves, multiple sine waves, square waves, and white noise.

(Refer to paragraph 5.10 for errors in analysis of narrow-band noise.)

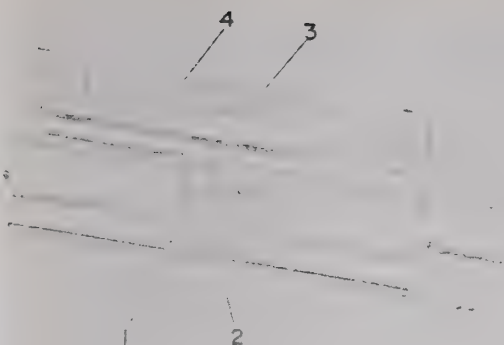
Since the potentiometer output is linear in db rather than in volts, the change in output voltage of the detector is significantly different for increasing and decreasing input signals. For example, a sudden 10-db increase would momentarily produce 3.16 volts, a change of 2.16 volts (error voltage) from its normal 1-volt value; a 10-db decrease would produce 0.316 volt, a change of -0.684 volt. To maintain comparable step responses in the two directions for such vastly differing signals, diode limiters are incorporated at the output of the detector. The level of limiting is set to produce similar transient responses for increasing or decreasing levels of at least 20 db (refer to paragraph 6.3). When adjusted correctly, the limiters will limit both halves of the symmetrical detector circuit to about 2 volts. Thus the error voltage will be limited to ± 1 volt.

4.4 PEN DRIVE CIRCUIT. The detector output is compared by emitter followers with a 1-volt dc reference obtained from the regulated 18-volt supply. An attenuator after the emitter followers changes the loop gain according to the potentiometer used. This is necessary because a 0.1-inch displacement from null on the 80-db potentiometer will produce a 2-db change in level, a 0.26-volt error voltage, while the same displacement on a 40-db potentiometer will produce a 1-db change in level, a 0.12-volt error voltage. Thus an attenuation factor of 2 is required when the 40-db potentiometer replaces the 20-db unit, and an attenuation factor of 4 when the 80-db potentiometer replaces the 20-db unit. A velocity feedback signal (see Figure 1.2) is also injected at this point. The sum of the error voltage (attenuated for the 40 and 80-db potentiometers) and the velocity feedback voltage is then amplified by a push-pull dc amplifier, drift-compensated by negative feedback. Two power transistors produce current through the drive coil or servo motor.

The servo motor consists of a center-tapped drive coil (2, Figure 4.1) wound on a lightweight lucite form which is positioned in the uniform magnetic field of an Alnico permanent magnet (4, Figure 4.1). The inter-

¹E.E. Gross, "Improved Performance Plus a New Look for the Sound-Level Meter", GENERAL RADIO EXPERIMENTER, Vol. 32, No. 17, October, 1958.

TYPE 1521-A GRAPHIC LEVEL RECORDER



1. Drive Coil 2. Potentiometer Wiper Arm
3. Magnet 4. Pen Motor

1. View of Magnetic Structure and Pen Motor.

When the current in the coil and the field from the permanent magnet is used to move the coil in a direction to reduce the error voltage. When the coil is properly positioned, the error voltage and the current become zero, and there is no further force on the coil. Hereafter, any slight movement from the correct position will produce an electrical restoring force on the coil. Full current flows through the coil when the displacement of less than 1/32 inch from the true position, giving in a high degree of static accuracy (refer to Figure 4.9). (This ability of the servo to provide a constant current in the drive coil for a displacement of less than 1/32 inch from null should not be confused with error. When the coil assembly is moving, velocity feedback reduces the servo loop gain and thus the error a proportional amount.)

The pen and the potentiometer wiper arm are mounted directly on the coil structure, so that backlash is eliminated.

VELOCITY FEEDBACK. A second winding on the magnetic structure generates a voltage proportional to the velocity (see 1, Figure 4.1). This damping voltage is fed into the input of the dc amplifier to reduce the gain at high frequencies and the time constant of the drive coil circuit. As a result, an adequate stabilization can be obtained consistent with the bandwidth of the pen servo and the desired accuracy. Slower writing speeds are obtained when the amount of damping voltage is increased.

LINEAR POTENTIOMETERS. The potentiometer winding forms shaped to obtain a scale of linearity. Padding resistors, tapped to the winding of the same size wire throughout the potentiometer, of the same degree of resolution is thus obtained at all points of the slider.

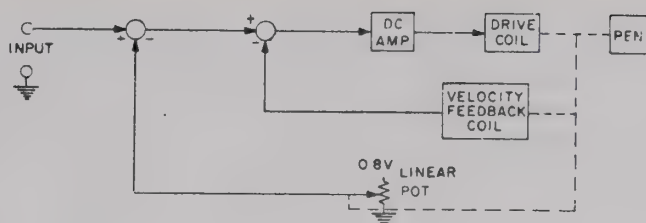


Figure 4.2. Block Diagram of Servo Loop for DC Recording.

4.7 DC RECORDING. Use of the linear potentiometer converts the Type 1521-A into a dc recorder. Figure 4.2 is a block diagram of the recorder servo loop for dc recording. The ac amplifier is bypassed and the input is compared with a dc voltage tapped off a linear potentiometer. The voltage on this potentiometer limits the full-scale sensitivity to 0.8 volt. The input impedance is limited to 1 kilohm owing to the base current of the input transistors. This current changes with temperature, but the change contributes negligible error with a 1000-ohm input impedance. The impedance can be increased if the effects of the current are included in the zero adjustment of the recorder. The input impedance can also be lowered, reducing sensitivity and drift. The low impedance may be more useful for recording current.

A zero adjustment (R19) adds a dc voltage in series with the input. Thus the zero position (input voltage zero) can be set to any point on the chart paper.

4.8 TRANSIENT RESPONSE AND DYNAMIC ERROR. The ability of the recorder to reproduce faithfully changes in the input level is a function of the saturated velocity (maximum writing speed), bandwidth, and degree of stability of the servo system. The application of a large step change in input level is often used to show the maximum saturated velocity capabilities and degree of stability (overshoot) of the recorder servo. However, most level changes actually encountered by the recorder will not be as abrupt as a step change, and the dynamic performance of the servo will here be considered with respect to other types of changes in input level that do not produce saturation. Two such types are the ramp (constant rate of level change) input and the sine wave.

The ramp-type input is often encountered in practice (as, for instance, in reverberation-time measurements). As the slope of the ramp increases, a point is reached where the error signal no longer remains constant; this is the limit of the linear operating range of the recorder. This maximum slope corresponds to the maximum writing speed of the recorder for a step-type input.

The response of the recorder to sine-wave inputs is discussed in paragraph 4.10.

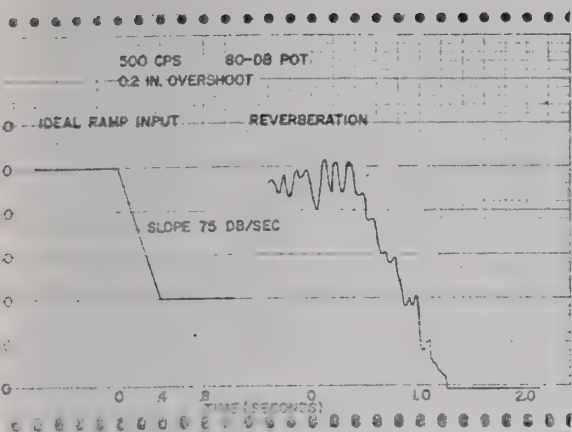


Figure 4.3. Recording of Ramp-Type Input.

The information in this section will be directly applicable only to ramp inputs, but will indicate the ability of the recorder to follow complex transients. It shows the effect of writing speed and potentiometer value (20, 40, or 80 db) on the speed capability of the recorder.

A servo-type recorder requires a finite position in order to drive the coil at a constant velocity. It is well to consider the difference between static and dynamic error. Static error, discussed in paragraph 4.9, is the small error required to move a stationary pen in order to overcome static friction. The dynamic error is measured when the pen is moving at a constant velocity. It is the difference between the true input and pen position at one instant of time. It will be much larger than static error, since the velocity feedback voltage subtracts from the error voltage the output of the detector. Dynamic error is measured as the difference between the true input and the 1-volt reference voltage. This error can be referred back to the

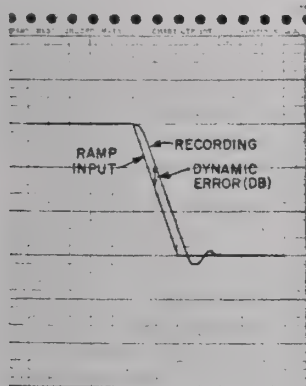


Figure 4.4. Dynamic Error for Ideal Ramp Input.

input of the ac amplifier so that the actual error on the recording can be indicated in db. Thus, a 0.1-volt error at the detector would be a 1-db error between the input and the recording on the chart paper at one instant of time. Figure 4.4 shows what this error would look like on the chart paper for an ideal ramp input. It should be emphasized that this error is not necessarily harmful, since for a simple ramp input it simply implies a delay in time.

The servo in the Type 1521-A Recorder develops a constant dynamic error for a constant-velocity input. Thus with a ramp input, a constant error will be observed except at the points of acceleration and deceleration (see Figure 4.4). The ratio of the input velocity to this constant error is sometimes referred to as the velocity-error constant (K_v). This velocity-error constant is the same for all three potentiometers. One must remember, however, to express the error in db and the velocity in db per second, or error in inches and velocity in inches per second. The graph in Figure 4.5 shows the error (db) for a ramp input.

The error is also a function of the WRITING SPEED control setting and the adjustment of the DAMPING control. Figure 4.6 shows the error for the 40-db potentiometer for different settings of these two controls. These curves show that a little overshoot, if it can be tolerated, will help achieve low error. The overshoot has been set at the factory to 0.1 inch (1 div on Type 1521-9428 chart paper) which we consider optimum for most measurements. If more overshoot can be tolerated, such as in reverberation-time measurements, decreased damp-

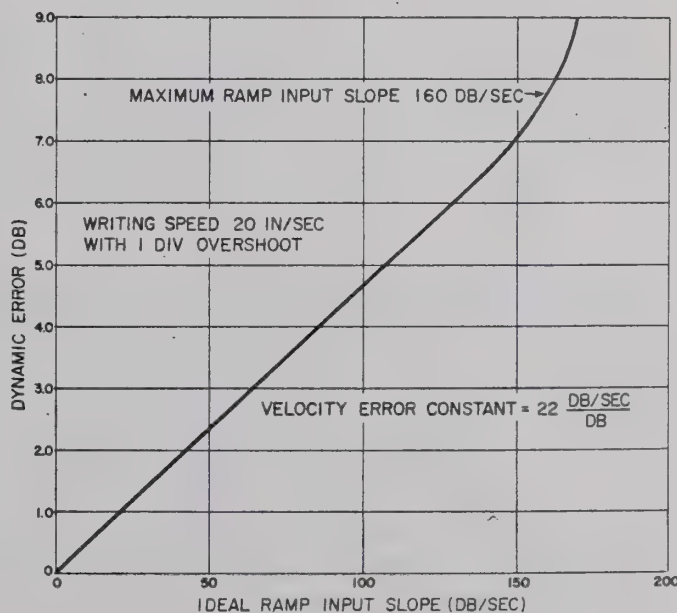


Figure 4.5. Dynamic Error for 20-, 40-, and 80-db Potentiometers.

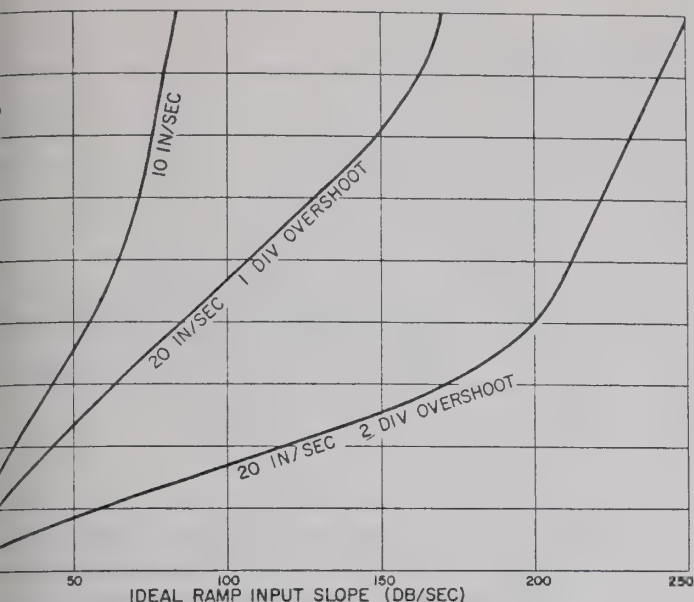


Figure 4.6. Dynamic Error For Various Writing Speeds (with 40-db Potentiometer).

duce the dynamic error. Also, it will increase the maximum input ramp velocity for the 40-db and 80-db potentiometers (explained in the following paragraphs).

The pen velocity is limited by the saturated current of the output transistors. Thus, if the velocity ramp input increases beyond this saturation velocity, the pen will not follow the input and the error will increase. This is noticeable as the ramp input is increased beyond 30 in./sec for the 20-db potentiometer, when the error increases very rapidly.

The maximum ramp input in inches per second that the recorder can follow is less for the 40- and 80-db potentiometers than for the 20-db unit because of the additional attenuation required for a constant loop gain. The additional attenuation occurring after limiting of the drive current reduces the maximum input voltage to the potentiometer. Because this voltage is reduced, the drive current is at a slower velocity so that the velocity voltage does not exceed the input voltage. The maximum ramp input in db per second is the same for all potentiometers.

How does this limit on the ramp input affect the measurement of reverberation time? This will depend on the method desired from the reverberation measurement. In some instances, the only information required is the decay time -- the time for a 60-db decay in sound level (refer to paragraph 5.5). Here the maximum ramp input mentioned previously limits the minimum reverberation time that can be measured to 0.3 second. However, reverberation decay is not an idealized ramp but contains superimposed oscillations caused by different room modes beating against one another. The measurement of these beats may be useful in analyzing the acoustic properties of the room.¹ The minimum reverberation time that can be measured with these beats

shown is 0.5 second (see Figure 4.7). For the measurement shown in Figure 4.7a, a reverberation decay was recorded on a tape recorder. It was then played back at slower and faster tape speeds to simulate longer and shorter reverberation times, with the Type 1521-A recording the decay. When the time scale is matched for each decay, there is little error in the average slope (proportional to reverberation time), yet the beats are filtered out by the Recorder as the effective reverberation time is decreased (Figure 4.7b, c). Note that although there is dynamic error, the average slope follows the ramp decay, delayed in time.

4.9 ACCURACY OF NULL (STATIC ACCURACY).

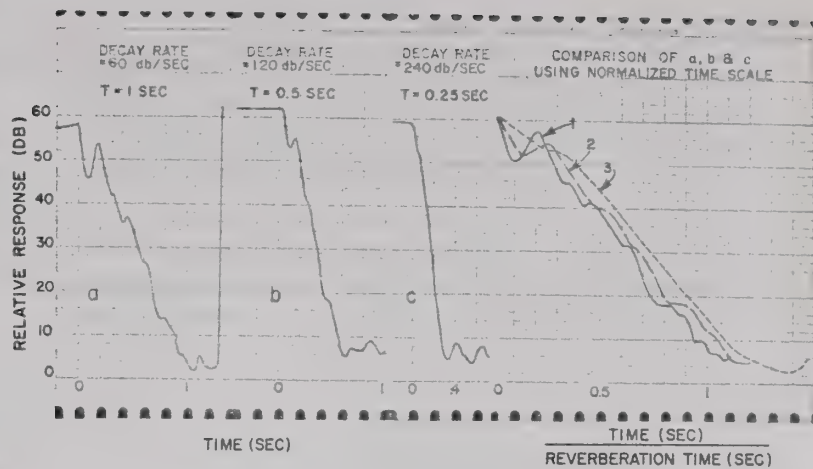
4.9.1 GENERAL. The accuracy of the null position depends upon many independent factors. Despite the many influences, at room temperature the error is less than one percent of full scale, if the input frequency is well within the pass band of the amplifier. The errors in determining the total accuracy of the recording are discussed in the following paragraphs.

4.9.2 DEAD SPAN. Dead span is the region where there is not enough current in the drive coil to overcome the static friction and move the coil to the true null position. The gain of the dc amplifier of the Type 1521-A is sufficient to reduce the dead span to less than 1/64 inch. Thus the error is less than ± 0.2 percent of full scale (± 0.08 db on the 40-db potentiometer).

4.9.3 POTENTIOMETER ACCURACY. The rated accuracy of the potentiometers is one percent of full scale,

¹C.L.S. Gilford, "The Acoustic Design of Talk Studios and Listening Rooms", *THE PROCEEDINGS OF THE INSTITUTION OF ELECTRICAL ENGINEERS*, Vol. 106, Part B, No. 27, May 1959, pp 249, 250.

Figure 4.7.
Maximum-Reverberation-Time Measure-
ments. Effective Reverberation Time
Decreased by Use of Multiple-Speed
Tape Recorder.



the accuracy of the 20- and 40-db potentiometers is usually better than 0.5 percent of full scale. The resolution of the potentiometer contributes negligible error compared with the dead-span error mentioned previously.

4.4 FREQUENCY ERROR. The frequency response of the ac amplifier can contribute errors at frequencies far from 20 cps and 200 kc. The amplifier is flat within 3 db from 20 cps to 200 kc. The response rolls off about 20 db at 20 cps, and is flat at the high end within the 3 db limit (± 1.5 db from reference). At frequencies above 100 kc, there are slight errors in the attenuator and also in the potentiometer due to capacitive loading of the wiper arm. These errors are less than 1.5 db at 200 kc. For extreme accuracy, a response recording of the oscillator can be used as the basis of compensating recordings of devices under test. For example, if the recorder ac amplifier rolled off 1 db at 20 cps, 1 db added to the final recording would remove frequency errors caused by the recorder.

4.5 TEMPERATURE EFFECTS. Table 4.1 shows

the drift for a typical recorder for the temperature ranges indicated.

4.10 SERVO BANDWIDTH. Servo bandwidth in a level recorder is defined for the motion of the pen, and is independent of the frequency response of the ac amplifier (20 cps to 200 kc). The servo acts as a low-pass filter, with the pen following level variations up to frequency cutoff. The cutoff frequency or servo bandwidth is the frequency at which the amplitude of the pen excursions drops to 0.707 times the amplitude at low frequencies (see Figure 4.8). The servo bandwidth is a

TABLE 4.1

Potentiometer	Drift (max variation, min to max reading, in % of full scale)	Temperature Range
DC Linear	2.5%	15 - 45° C
20, 40, 80 db	1%	15 - 33° C
20, 40, 80 db	2.5%	0 - 45° C

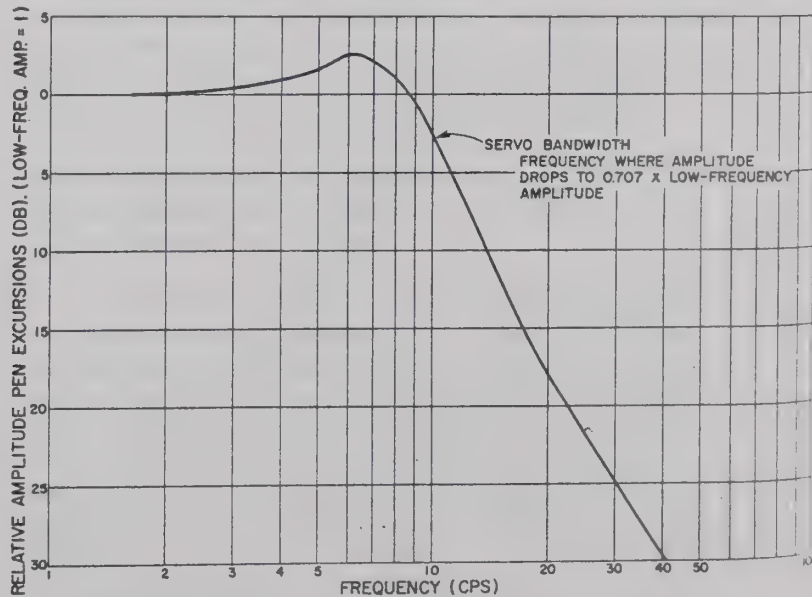


Figure 4.8. Servo Frequency Response.

TYPE 1521-A GRAPHIC LEVEL RECORDER

ication of the recorder capabilities for small in amplitude.

servo bandwidth of the dc potentiometer is asured. A low-frequency signal is fed directly recorder input, and the cutoff frequency is This is somewhat more difficult with the log- potentiometers, since a high-frequency signal modulated with a low-frequency signal.

bandwidth depends upon the amplitude of frequency pen excursions. If a plot is made of versus amplitude of excursions, the band- remain constant as the amplitude is increased ng speed becomes a limitation. (This charac- shown in Figure 4.9 for all four potentiom- a given frequency the maximum slope of a increases directly with amplitude. Because order writing-speed limitation, the servo band- decrease as the amplitude increases. Re- nals above this frequency will not only have de error, but will be very distorted. The am- which writing speed becomes a limitation in- s the dynamic range of the potentiometer de- Refer to Figure 4.9.) But this amplitude, when to db, remains constant for the logarithmic ters.

maximum small-signal bandwidth varies di- the setting of the DAMPING control. In Fig- when the overshoot was increased from 1 to

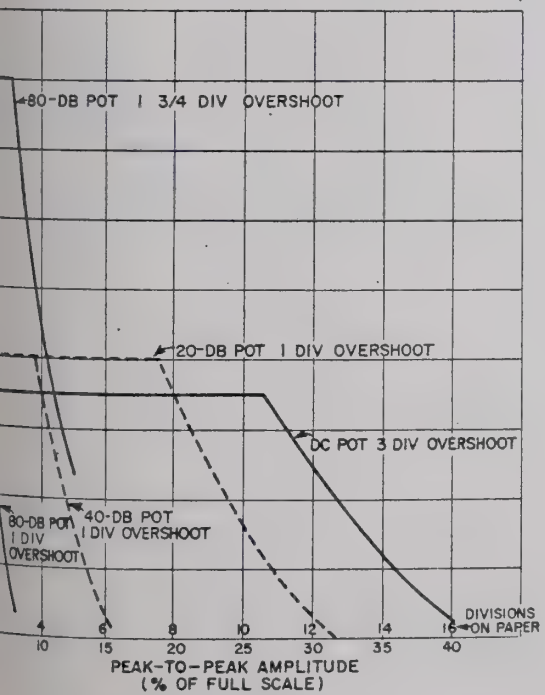


Figure 4.9. Servo Bandwidth vs Amplitude of Excursions.

1-3/4 divisions, the bandwidth increased 40%. This increase in bandwidth, in conjunction with the increase in maximum ramp slope (refer to paragraph 4.8) is useful for reverberation-time measurements.

The servo bandwidth decreases as writing speed is decreased. This is shown in Table 4.2 for a typical recorder. There is no amplitude limitation for the slower writing speeds, the bandwidth remaining constant even for full-scale excursions of the pen.

TABLE 4.2
SERVO BANDWIDTH FOR SLOW
WRITING SPEEDS
(Typical Recorder)

Position of Writing Speed Control	Servo Bandwidth (cps)	
	20-, 40-, 80-db pots	DC pot
10	5.0	1.2
3	0.80	0.45
1	0.25	0.20

4.11 HIGH-Q ANALYZERS. With high-Q analyzers, there are some fundamental problems that are independent of recorder characteristics. If the analyzer is swept too fast, errors will occur in the magnitude, frequency, and effective bandwidth of the analyzer.

Figure 4.10 shows a recording of a frequency analysis made with a fixed-frequency input to the Type 760-B Sound Analyzer. This shows a comparison of the correct recording and a recording in which the Analyzer was swept too fast. Note the error in magnitude, shift in center frequency, and increased effective bandwidth of the filter. The oscillations occurring on the decay side indicate that the Analyzer was swept too fast. These oscillations are caused by beating between the input frequency and the frequency of the high-Q circuit after energy has been stored.

The rate at which an analyzer may be swept for a given error is proportional to the square of the filter bandwidth.¹ Thus for a constant-Q filter, the sweep speed in cycles per second² for a given error increases as the tuned frequency is increased. The General Radio Analyzers described in this manual are constant-Q filters. Thus the low-frequency ranges should be swept fairly slowly. Table 4.3 shows the errors measured for

¹V. F. Barber, "The Optimum Performance of a Wave Analyzer", *ELECTRONIC ENGINEERING*, May, 1949, pp 175-9.

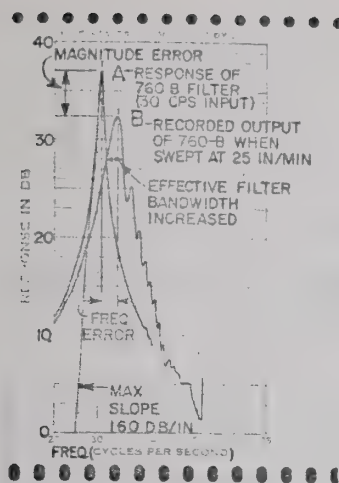


Figure 4.10. Errors from Sweeping High-Q Analyzer Too Fast.

the Types 760-B, 1564-A, and 1554-A Analyzers at the maximum recommended sweep speeds given in Table 3.4.

In analysis at higher frequencies (above 750 cps with the Type 760-B), the sweep speed is limited by the writing speed limitations of the recorder. The maximum slope of the curve shown in Figure 4.10 is 160 db/inch. The shape of this curve on the chart will be relatively constant with frequency, since the frequency scale is approximately logarithmic. At a paper speed of 30 div./min, this slope would correspond to 20 db/sec. The pen would ordinarily follow such a slope without any difficulty; with a high-Q filter, however, the slope quickly changes near the filter peak from +20 db/sec to -20 db/sec as the analyzer is swept by the input frequency. Thus the dynamic error (refer to paragraph 4.8) shows up directly as a level error on the recording. This error places a final limitation on the sweep speed if the pen has to travel over large distances.

TABLE 4.3
ERRORS AT MAXIMUM RECOMMENDED SWEEP SPEEDS

	Frequency Band (CPS)	Sweep Speed (Chart Div/Min)	Magnitude Error (DB)	Frequency Error (% of f_0)	% Increase in Filter Bandwidth
760-B	25 - 75	10	-0.8	+1.3	+70
	75 - 250	10	-0.25	+2.0	small
	250 - 750	30	-0.3	+0.7	+20
	750 - 2500	30	-0.15	+0.7	small
	2500 - 7500	30	-0.15	+0.7	small
1564-A and 1554-A Narrow Band	25 - 250	30	0	+0.8	0
	250 - 2500	100	0	+0.5	+ 8
	2500 - 25,000	100	0	+0.3	+ 2

Potentiometer = 40 db; Writing Speed at 20 in./sec. Damping adjusted for 0-db overshoot.

Section 5

APPLICATIONS

AL. This section describes some of the measurements possible with the Graphic Level Recorder. Although General Radio equipment is recommended, equipment of other manufacturers may be used except for equipment whose dials are to be connected to the recorder by the standard link units. Link cables and recorder paper, have been designed for use with General Radio instruments.

In general, the paper speed, writing speed, and pen should be chosen to optimize the response of the recorder and the accuracy and readability of the recording. An exception is the slow writing speeds, where the speed of response or servo bandwidth, acting as a low-pass filter for variations in the signal, is used to filter out high-frequency variations, taking an average of the true level level. However, it is possible to reduce the writing speed to the point where desired level variations are clearly visible. Comparison with a preliminary recording at a fast writing speed will indicate this condition.

Following are some general recommendations: Use the smallest-range potentiometer that will cover the dynamic range of the recorded signal. Insure maximum precision and accuracy.

For most measurements, choose the fast (20 in./sec) speed. This insures optimum response characteristics of the recorder. Slow speeds are for smoothing. (Refer to paragraph 4.8 for a discussion of smoothing.)

Choose a paper speed that will not crowd the recording on the paper. In general, the faster the recording, the greater the paper speed must be to avoid crowding.

TYPE 1551 SOUND-LEVEL METER. The recorder, when used with the Type 1551 Sound-Level Meter, is well suited for acoustic measurements. A discussion of measurements with the Sound-Level Meter may be found in the Operating Instructions for the Type 1551, in the HANDBOOK OF NOISE MEASUREMENT, published by General Radio Company, and in several

General Radio Experimenter articles, including "Improved Performance plus a New Look for the Sound-Level Meter" by E. E. Gross, in the October, 1958, issue.

An adaptor cable assembly supplied with the recorder can be used to connect the OUT jack of the Type 1551 to the recorder INPUT terminals. The recorder can be calibrated to indicate sound level in decibels above the standard reference level (0.0002 μ bar at 1000 cps) as follows:

- a. Turn both instruments on, with the recorder connected to the Sound-Level Meter as described above.
- b. Set the Type 1551 attenuator switch to 130 CAL.
- c. Set the Type 1551 WEIGHTING switch to CAL, and adjust the CAL control for a 10-db meter indication. A fixed-level 1-kc signal is now being fed into the recorder.

- d. Adjust the recorder INPUT ATTENUATION and CAL controls to bring the pen to full scale with the 20- and 40-db potentiometers (to 20 db below full scale with the 80-db potentiometers). The chart paper now corresponds to the meter scale, with full scale on the meter (10 db) representing full scale (20 db below full scale with the 80-db potentiometer) on the chart paper.

- e. Readjust the Type 1551 CAL thumbset control until the meter reads within the white CAL area.

The Sound-Level Meter may now be operated in the normal manner, with full scale on the chart paper calibrated to represent 10 db plus the reading on the Type 1551 attenuator. The slower writing speeds can be used to provide a recording of averaged sound level (see Figure 5.1).

Ordinarily the recording will not be limited by the characteristics of the Sound-Level Meter. With the 80-db potentiometer, however, the maximum recordable level will be about 10 db below full scale on the paper. The residual noise from the Sound-Level Meter will appear near the bottom of the recorder scale for attenuator switch settings of 70 db and higher on the Sound-Level Meter. Refer to the HANDBOOK OF NOISE MEASUREMENT, published by General Radio Company, for a discussion of errors and corrections when the recorded level is near this residual noise level.

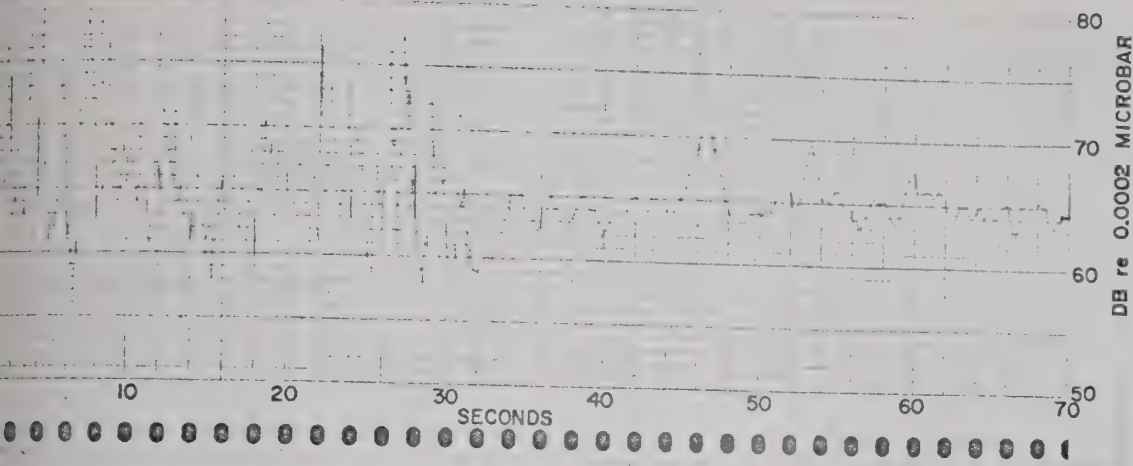


Figure 5.1. Recording of Noise Level in a Cafeteria with both Fast and Slow Writing Speeds and 40-db Potentiometer.

LEVEL SOUNDS (above 80 db). For the measurement of high-level sounds, the Type 759-P25 Dynamic Microphone Assembly and Type 1551-P1 Condenser Microphone Assembly have high enough outputs to work directly to the recorder. Table 5.1 shows the range of sound levels that can be made either with the Sound-Level Meter or with microphone connected directly to recorder. For very high sound levels, the input impedance of the recorder must be increased to avoid loading down the microphone. A cathode follower in the microphone preamplifier. The value of the series resistor that should be used

between the microphone and the recorder is given in Table 5.1.

The equipment should be calibrated by means of the Type 1552-B Sound-Level Calibrator and a suitable oscillator source, such as the Type 1307-A Transistor Oscillator.

5.4 VIBRATION LEVEL VS TIME. Vibration level vs time can be recorded with the output of the vibration measuring system (Type 761-A Vibration Meter or an array consisting of Type 759-P35 Vibration Pickup,

TABLE 5.1
RANGE OF SOUND LEVELS WITH SOUND-LEVEL METER
OR DIRECT MICROPHONE CONNECTION

Microphone	Dynamic Range of Sound Levels	Series Resistor (see Figure 5.2)
Type 1551-B Sound-Level Meter	30-150 db	0
Type 1551-P1L Condenser Microphone	80-130 95-150	Requires cathode follower between microphone and recorder.
Type 1551-P1H Condenser Microphone	95-145 110-170	Requires cathode follower between microphone and recorder.

TYPE 1521-A GRAPHIC LEVEL RECORDER

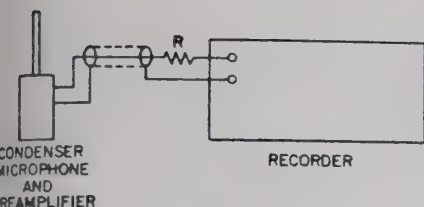


Figure 5.2. Direct Connection of Microphone to Recorder.

P36 Control Box, and Type 1551 Sound-Level Meter, connected to the recorder INPUT terminals. The Type 1551 Sound-Level Meter has a low-frequency limit of 20 cps, also the low-frequency limit of the Type 761-A Vibration Meter, but cannot be used below 20 cps.

To make full scale on the chart paper correspond to full scale on the Type 761-A Vibration Meter, proceed as follows:

1. Connect the output of the Vibration Meter to the recorder INPUT terminals.

2. On the Vibration Meter, set the METER SCALE to CAL and push the METER READS CAL 1 button. Adjust the CAL screw-driver control so that the meter reads 50 on the upper scale.

3. Turn the recorder pen to 6 db below full scale by adjusting the recorder INPUT ATTENUATION and CAL controls. Once set, these controls should not be readjusted.

4. Recalibrate the Vibration Meter as outlined on the instruction manual for the instrument.

5. Now set full scale on the Type 761-A meter now corresponding to full scale on the Type 1521-9428 Chart Paper. The chart paper shows the conversion of the chart paper from the meter scale.

6. Adjust the maximum vibration level near full scale by adjusting the controls on the Vibration Meter; do not readjust the recorder controls.

The Type 1551 Sound-Level Meter, used in conjunction with the Type 759-P35 Vibration Pickup and P36 Control Box, comprises an inexpensive measuring system, especially suited for use with the recorder. When ordering the Type 759-P35 and P36, be sure to complement an existing Type 1551 Sound-Level Meter with a microphone sensitivity of the Sound-Level Meter (checked inside the case). The vibration attachment should be factory-calibrated to this sensitivity.

The calibration is as follows: first calibrate the chart paper on the Sound-Level Meter as described in paragraph 5. Set up the vibration-measuring equipment as described in its instruction manual. The attenuator on the Sound-Level Meter should be set so that the meter reading is almost full scale, to in-

RESPONSE IN DB	761-A METER READING	FULL SCALE ON METER	
		31.6	100
40	251	79.4	
	200	63.1	
	159	50.1	
	126	39.8	
30	100	31.6	
	79.4	25.1	
	63.1	20.0	
	50.1	15.9	
20	39.8	12.6	
	31.6	10.0	
	25.1	7.94	
	20.0	6.31	
10	15.9	5.01	
	12.6	3.98	
	10.0	3.16	
	7.94	2.51	
0	6.31	2.00	
	5.01	1.59	
	3.98	1.26	
	3.16	1.00	

Figure 5.3. Conversion of Chart Paper from db to RMS Values of Velocity, Acceleration, and Amplitude.

sure maximum signal-to-noise ratio. The recorder readings can be converted to acceleration, velocity, or displacement by means of conversion factors marked on the control box and by the use of charts supplied with the control box.

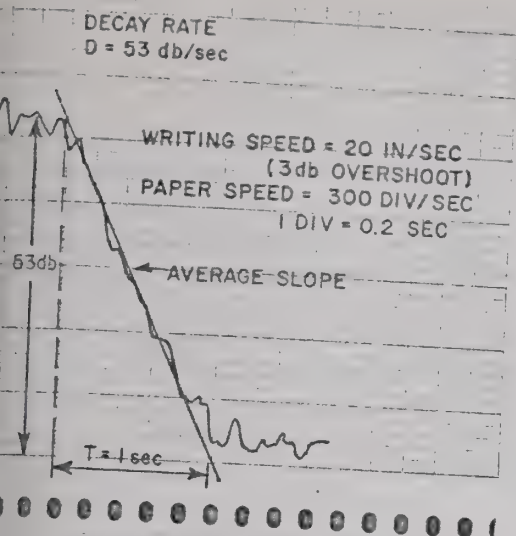
5.5 REVERBERATION TIME AND DECAY RATE. A common method of determining the acoustic properties of a room is to fill the room with sound, suddenly silence the source of the sound, and measure the rate of decay of the sound in the room. This rate of decay can be defined in two ways. The common term is reverberation time (T), the time taken for the sound to decay 60 db in sound pressure level. Recently, however, a more useful term, decay rate (D) has been suggested.¹ There are numerous reasons mentioned in the reference¹ for the preference of decay rate. One of the most important is that the decay in sound level can be described more completely, differentiating initial decay rate from average decay rate.

The decay rate of sound pressure level, in decibels per second, can easily be converted to reverberation time by the following formula:

$$T = 60/D \text{ where } T = \text{reverberation time (second) and } D = \text{decay rate (db/sec)}$$

The Type 1521-A Graphic Level Recorder is a most convenient means of making this measurement, giving a permanent record of the sound decay (Figure 5.4) or reverberation time (Figure 5.5). The Type 1521-A

¹Robert W. Young, "Sabine Reverberation Equation and Sound Power Calculations", *JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA*, Vol 31, No. 7, July 1959.



4. Decay Rate for 1/3-Octave Band of Noise at 500 cps.

decay rates as fast as 200 db per second (time of 0.3 second). When it is necessary to measure beats during the sound decay, the decay rate is limited to 120 db per second. (Refer to discussion of maximum decay rates.) The 1521-A is used with a multiple-speed recording system. Much faster decay rates can be recorded later in this section).

Random sound sources are commonly used for reverberation measurements. One of the best is a band of random noise. Measurement is simple and offers results more reliable than those produced by other types of sound sources. For a complete discussion of reverberation measurements and a comparison of various methods refer to *ACOUSTIC MEASUREMENTS*, 1949, John D. Pierce, p. 806.)

Figure 5.6 shows the setup for reverberation measurement. A random-noise generator whose spectrum is flat over the frequency range of interest is used. A third-octave-band filter follower is tuned to the desired frequency of

2. "Random Sound Field in Reverberation Chamber," *THE ACOUSTICAL SOCIETY OF AMERICA*, October 1959.

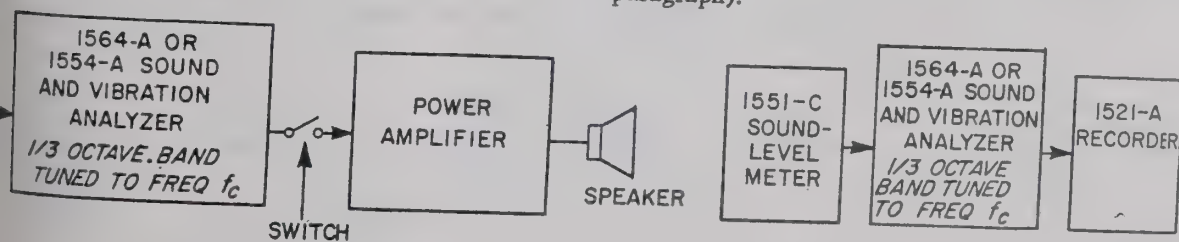


Figure 5.6. Setup for Reverberation Measurements.

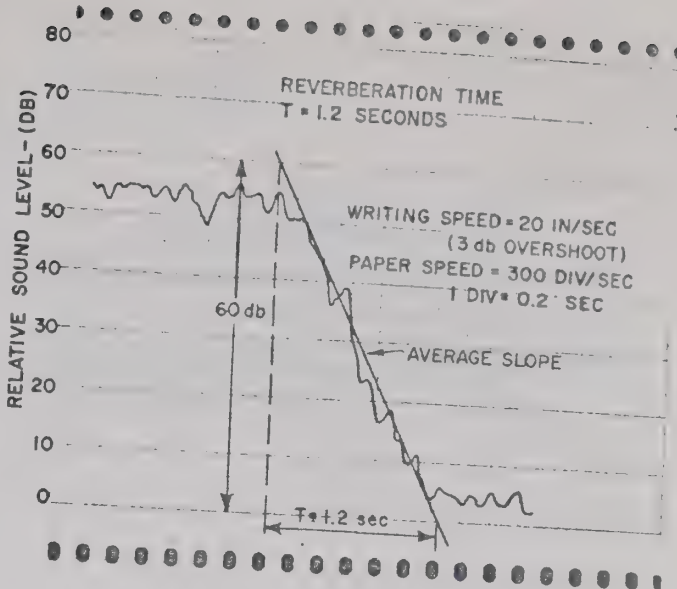


Figure 5.5. Reverberation Time for 1/3-Octave Band of Noise at 500 cps.

measurement, generally 125, 250, 500, 1000, 2000, or 4000 cps. A switch after the filter permits instant silencing of the source. A power amplifier raises the level at least 40 db above the ambient noise level of the room or chamber. The type of loudspeaker is not critical, but its frequency response should be reasonably smooth, and it should not cause excessive distortion at the levels used. The preferred placement of the speaker is usually in a corner, where the maximum number of vibration modes are excited.

The microphone should be placed far away from the source to avoid excessive pickup of the incident sound wave. A microphone in a corner of the room is often ideal, since it will there pick up the maximum number of vibration modes. The Type 1551 Sound-Level Meter includes an excellent microphone and amplifier combination for this measurement. A third-octave or octave-band filter tuned to the source frequency used after the microphone amplifier will help to reduce background noise. If, for example, the ambient noise level in the room is 60 db, such a filter may reduce it to 40 db or even lower in the filter band. This means 20 db less output required of the loudspeaker. Only one filter is necessary if a tape recorder is used (described later in this paragraph).

TYPE 1521-A GRAPHIC LEVEL RECORDER

tain the fastest writing speeds (in db/sec),
db potentiometer and set the DAMPING con-
4 db overshoot.

the random-noise source, recorder, and other
have been turned on, the measurement is per-
allows:

t the recorder pen, using the INPUT AT-
N and CAL controls, so that the ambient
is at the 0-db end of the chart for the 80-db
er, just off scale for the 40-db potentiometer.
t the noise source for a 40- to 60-db level
nt as indicated on the recorder paper.

on the recorder chart drive, set for maximum

off the noise source, using the switch shown
6.

the decay rate from the chart in the follow-
(see Figure 5.4):

ge the slope with a line drawn on the chart

the decay in sound level for a convenient
time (1 sec, 0.5 sec, 0.2 sec).

polate to find the decay in level for 1 second.

decay rate in db per second.

reverberation time from the chart in the fol-
lower (see Figure 5.5):

ge the slope with a line drawn on the chart
and the line from 0 to 60 db.

the time interval for this 60-db change in
on the horizontal scale. For the fast paper
div/sec), one division equals 0.2 second.

field use, sound decay can be recorded with
tape recorder, and later played back into the
el recorder. Only one 1/3-octave-band filter
l for this type of measurement, since the
output filters are used at different times.
(5.7 for the measurement setup.)

mphasis in the tape-recorder preamplifier
eping the recording level low above 1 kc to
ating the tape. Table 5.2 indicates the sug-
gording level for various frequencies.

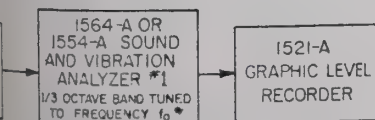
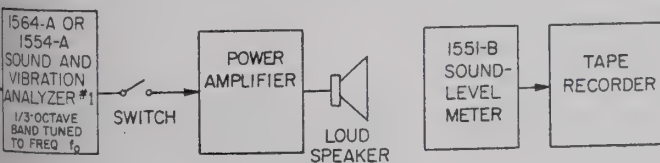


TABLE 5.2

TAPE-RECORDING LEVEL

FOR REVERBERATION-TIME MEASUREMENTS

Frequency of Source	Recording Level (VU)
less than 1 kc	0
2 kc	-3
4 kc	-8
6 kc	-12
8 kc	-14

A multiple-speed recorder can be used to measure decay rates much faster than 200 db per second, if the decay is recorded at the fast tape speed and played back at a slower speed. The filter following the tape recorder should then be tuned to a fraction of the source frequency, f_0 , corresponding to the amount the speed was reduced. This also permits the observation of many irregularities occurring in the decay that might otherwise be filtered out by the recorder. Some two-channel tape recorders permit even greater portability, since the noise source can be prerecorded on one channel, obviating the presence of generator and filter at the scene of measurement.

5.6 VU RECORDINGS. By definition, the only accurate method of measuring VU of a complex waveform is with a VU meter. Any other device, such as a level recorder, should be recognized as providing only an approximation.

The ballistics of a VU meter and of a level recorder are different. If a sinusoidal voltage giving reference deflection is suddenly applied to a VU meter, the meter pointer will reach 99 percent of the reference deflection in 0.3 second.¹ The meter scale, however, is

¹IRE Standards on American Recommended Practice for Volume Measurements of Electrical Speech and Program Waves", 1953, *PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS*, Vol 42, No. 5, May 1954.

Figure 5.7. Setup for Portable Reverberation Measurements.

GENERAL RADIO COMPANY

TABLE 5.3
CHARACTERISTICS FOR VU MEASUREMENT

Characteristics (Reflection)	Writing Speed	
Rate db/sec	20-db pot.	40-db pot.
22		
24		
30		
31	50 db/sec =	30 db/sec =
34	10 in./sec	3 in./sec.
39		
46		100 db/sec =
58		10 in./sec.
77	100 db/sec =	200 db/sec =
286	10 in./sec.	20 in./sec.

in db per second is not constant. On the other hand, has a speed control. If the level recorder is to approximate a VU meter, therefore, its writing speed should be set to correspond to the VU meter value to be measured (refer to the preferred region for measurement on a scale to +3 VU. To correspond in this region the writing speed should be set to 10 in./sec for the potentiometer, or 3 in./sec for the

potentiometer will depend upon the level recorded. In this respect, a level recorder is better than a VU meter, since it will also record the level. Thus more than 20 db of range (a VU meter) may be useful. The level recorder and in the VU meter. That in the recorder is an rms reading VU meter an average-reading device is 1 db for noise, square waves on.¹

RESPONSE MEASUREMENTS USING
FREQUENCY GENERATOR. The
of transducers and electrical de-
tically plotted with the recorder and
frequency Generator (refer to para-
5.8 and 5.9 show examples.

5.8 FREQUENCY RESPONSE MEASUREMENTS OF
PHONOGRAPH REPRODUCERS.² Automatic frequency
response measurements of stereophonic phonograph car-
tridges are made possible by use of the Type STR 100
Stereophonic Frequency Test Record produced by CBS
Laboratories. This record has a frequency-swept band
recorded from the output of a Type 1304-B Beat-Fre-
quency Audio Generator driven by a Type 1521-A Re-
corder. The swept band is recorded first on one channel,
then on the second channel. Thus a recorded frequency
response of a given channel can be made. If the recorder
remains connected to this channel, the second frequency
swept band gives a measurement of the cross talk be-
tween the two channels versus the frequency.

5.9 CONSTANT SOUND-PRESSURE LEVEL. The servo
system of the Type 1521-A Graphic Level Recorder can
be used to control sound-pressure level or voltage to
obtain flat frequency response. Such control is useful
in a number of applications, including, for example,
microphone calibration.

A convenient method of microphone calibration
uses a source of sound level that is flat with frequency
at the location of a microphone to be tested. This is
difficult even with a very good loudspeaker and anechoic
chamber. However, if two microphones are placed side-
by side in an anechoic chamber, the Type 1521-A Graph-
ic Level Recorder will control the sound level to the
reference microphone to within 1/4 db of the frequency
response of this microphone. The dynamic range of the
control is limited only by the potentiometer used, a 40-
db potentiometer covering most applications. A con-
denser microphone should be used as the reference,
since the degree of flatness of sound-pressure level
with frequency is only as good as the microphone. The
microphone under test is placed next to the reference
microphone in an anechoic chamber, so that the sound-
pressure level will be constant with frequency in the
immediate vicinity of the reference microphone. The
output of the test microphone is then recorded on a sepa-
rate recorder as the frequency is swept, the resulting
plot being the frequency response of the microphone.
Figure 5.10 shows recordings of a microphone calibra-
tion made in the frequency range from 70 cps to 1 kc.

This method of microphone calibration is not per-
fect, however. At frequencies above 1 kc the second
microphone placed near the reference microphone dis-

1 "A New Look for the Sound-Level Meter",
RADIO EXPERIMENTER, October 1958,

²For complete details refer to "Automatic Measurement of Phonograph
Reproducers", by B. B. Bauer, General Radio Experimenter, January-
February 1962, obtainable upon request.

TYPE 1521-A GRAPHIC LEVEL RECORDER

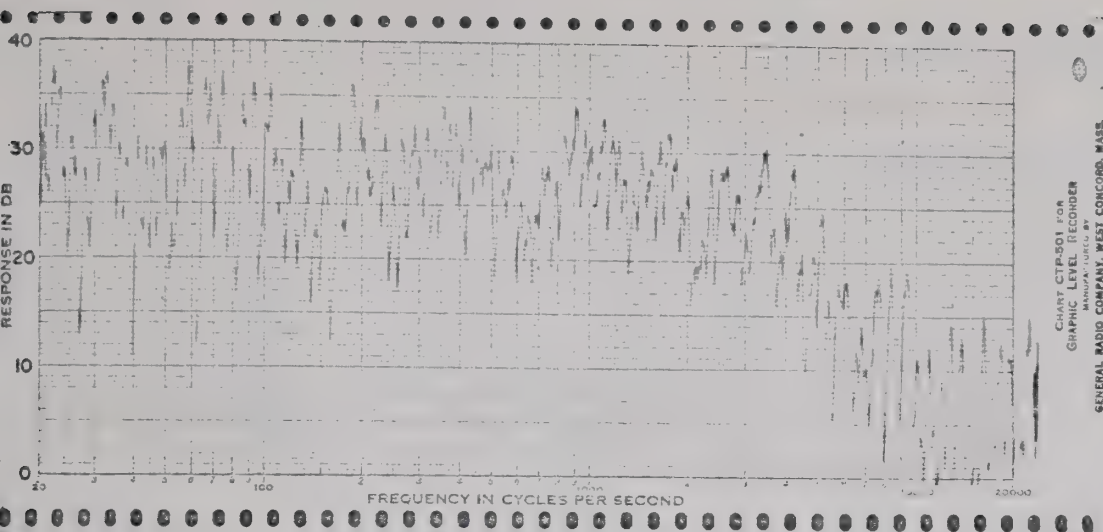


CHART CTP-501 FOR
GRAPHIC LEVEL RECORDER
MANUFACTURED BY
GENERAL RADIO COMPANY, WEST CONCORD, MASS.

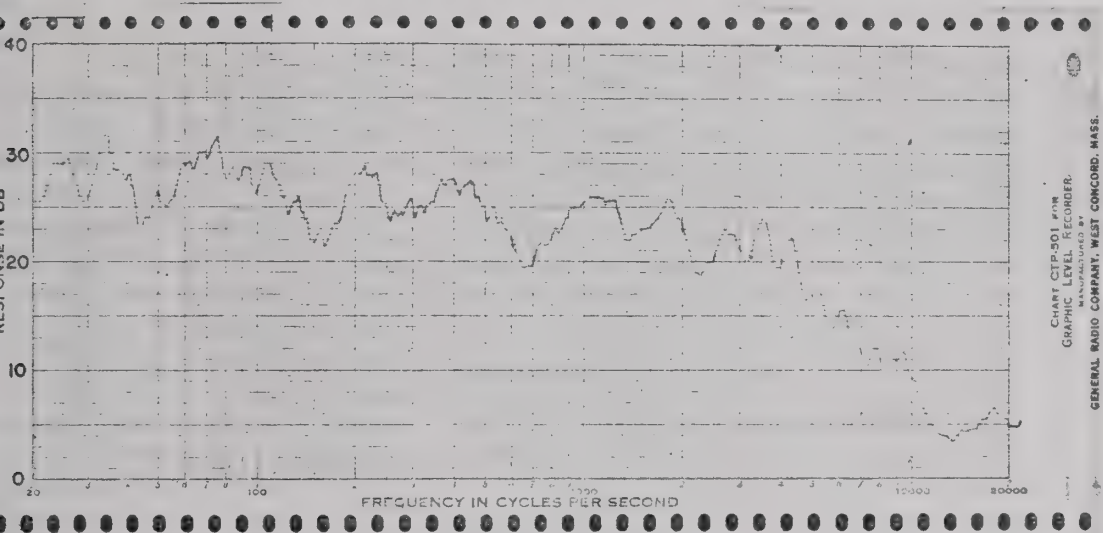


CHART CTP-501 FOR
GRAPHIC LEVEL RECORDER
MANUFACTURED BY
GENERAL RADIO COMPANY, WEST CONCORD, MASS.

Figure 5.8. Recording of Frequency Response of a Public-Address System Taken with (A) 20 in./sec and (B) 3 in./sec Writing Speeds.

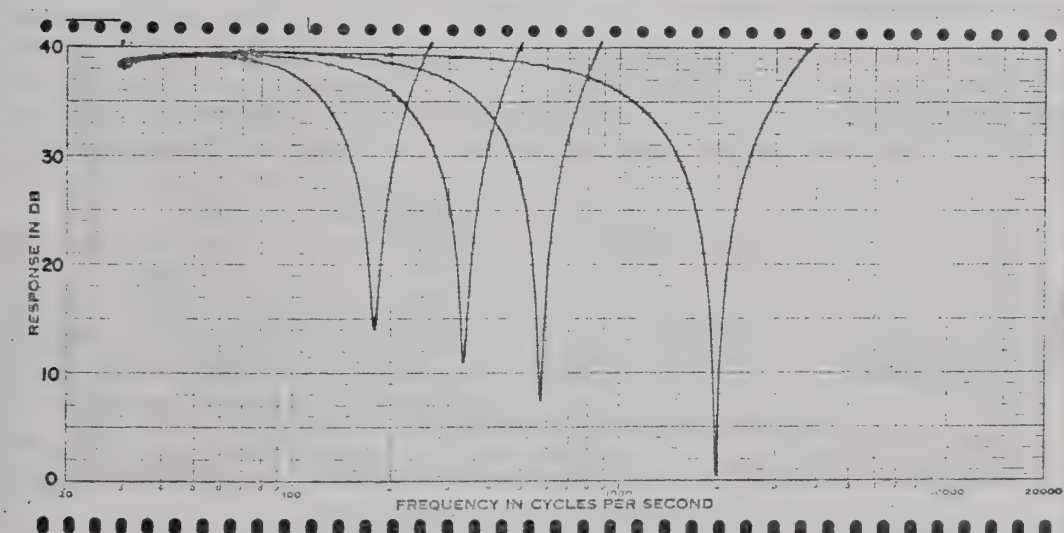


Figure 5.9. Recording of Transmission Characteristics of an Adjustable Notch Filter for Four Different Frequency Settings.

TABLE 5.4 (Continued)

Equipment	Description
Speaker	gain of 4. Output impedance should be matched to loudspeaker with transformer.
1551-P1L Condenser Micro-System	Produces low-distortion (below 3%) sound in frequency range of interest. Must handle maximum power from amplifier above. Reference microphone and preamplifier shown in Figure 5.11.
Attenuator	Input impedance at least 10 k or above. Output impedance 1 kc or less. Resistors are 5%, 1/2 watt rating. The output resistor (1 k) should be connected directly between points 103 and 110 on the etched board, so that hum pickup will be low.
1304-B Beat-Frequency Generator	Signal source.

be used (10 or 20 in./sec) with a slow 10 div/min).

the attenuator after the microphone preamplifier. Turn the CAL control on Recorder No. 1 until the desired pressure level is obtained. An attenuator after the Type 1551-P1L Condenser Micro-System will give a sound level of about 100 db.

the oscillator through the desired frequency range. Adjust the gain of the amplifier between point 103 and 110 on the etched board, if necessary, to get the pen on the paper. Control is obtained by adjusting the pen is free to move.

COMPARISON OF LEVELS. The recorder can be used to measure the ratio in db of two signal voltages, provided the reference voltage is constant within 9 db. The action is as follows:

the signal voltages to be compared is recorded as the reference voltage in the recorder. The reference voltage is applied to the input of the recorder. The recorder will then plot the ratio of the two signal voltages. One signal is compared with the reference

voltage (the other signal, rectified). The accuracy of this plot will depend on the variation in the reference voltage. The extent of the correction for variation in the reference voltage can be seen from Table 5.5.

One example of this comparison is the frequency response measurement of a loudspeaker where the output of the Type 1304-B Beat-Frequency Generator is fed through a power amplifier to the loudspeaker. If the frequency response of the power amplifier is not flat, correction can be made by use of the power amplifier output as the voltage fed into the detector circuit (see Figure 5.12). Note that this will not correct variations greater than 18 db.

TABLE 5.5
SOURCE LEVEL VARIATIONS

Total Variation Source Level (db)	Corresponding Variation of Recorder Pen (db)
18 (max)*	0.4
15 *	0.2
10	0.1

* D105 and D106 disconnected from Circuit

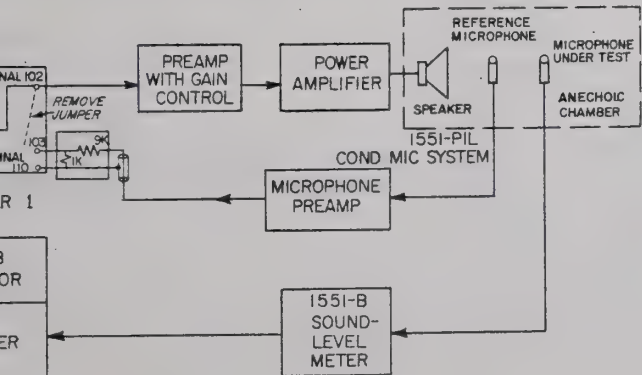
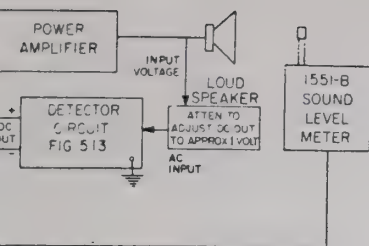


Figure 5.11. Setup for Microphone Calibration.



System Used to Measure Ratio
as a Function of Frequency.

Circuit used to convert the ac signal
voltage is shown in Figure 5.13.

Wiper between terminals 115 and
ground. Connect the negative side of
terminal 115 and the positive side
board (see Figure 5.12).

of the circuit as shown in Figure
on: the input to the detector cir-
cuits input to the recorder.

level of the loudspeaker as de-
termined by oscillator or power-amplifier gain

Wiper between terminal 115 and TP4
(terminal 115), adjust the attenuator until
the voltage is about 1 volt.

OVERSHOOT control fully coun-
ter-clockwise, the CREEP control fully clock-

For maximum correction range
solder diodes D105 and D106 from
terminals 113 and 114. (Otherwise a
short would result in a low-frequency
level of the dc reference level.)

Wiper and place the pen on scale
of the ATTENUATION control.

Wiper between the loudspeaker and
detector circuit (See Figure 5.12) over a
range of frequencies. The pen does not move significantly. Set
the wiper at midpoint to ensure the maxi-

imum voltage going to the recorder input
is as shown in Figure 5.12.

speaker input voltage.

5.11 FREQUENCY ANALYSIS. Frequency analysis of
sound, vibration, noise, and other complex waveforms
can be made with the Type 760-B Sound Analyzer, or
the Type 1564-A or 1554-A Sound and Vibration Anal-
yzer. In the measurements described in paragraphs
5.2, 5.3, and 5.4, the analyzer can be placed between
the Type 1551 Sound-Level Meter or Type 716-A Vibra-
tion Meter and the recorder, thus analyzing the sound,
vibration, or noise.

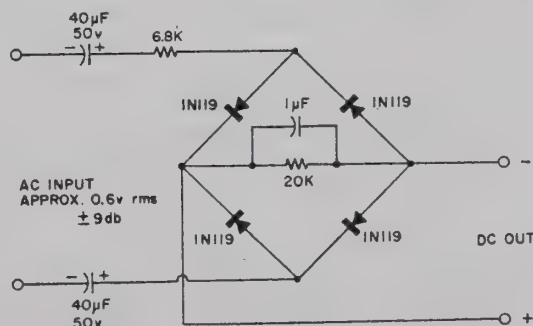
To set the 0-db level, the complete frequency
range should first be passed through the analyzer into
the recorder. On the Type 1554-A, set the BANDWIDTH
switch to ALL-PASS; on the Type 760-B, release all the
frequency buttons. Set the analyzer gain so that the me-
ter reads upscale (for maximum signal-to-noise ratio).
The recorder can then be set to some arbitrary 0-db
reference by means of the INPUT ATTENUATION and
CAL controls.

Before proceeding with the analysis, give careful
consideration to the choice of weighting used on the
Sound-Level Meter, which is discussed in the operating
instructions for the Sound-Level Meter and, more fully,
in the HANDBOOK OF NOISE MEASUREMENT, avail-
able from General Radio Company.

In the analysis, the maximum recorded level will
be a little lower than the total level in the all-pass
band. It may be desirable to use this maximum level as
an arbitrary reference. The recorder pen can be set to
this reference level by means of the INPUT ATTENU-
ATION and CAL controls.

When noise is analyzed through narrow-band fil-
ters (one octave or less), an error occurs in the quasi-
rms detector circuit. This error is about -3 db at 25 cps,
and decreases gradually with increasing frequency, be-
coming negligible above 25 kc. This error can be re-
moved by the addition of 1- μ f capacitors in parallel
with C121 and C122. These capacitors will affect the
servo bandwidth and transient response in the fast writ-
ing speeds (20 and 10 in./sec); however, the slower
speeds are generally preferred in this measurement.

Figure 5.13. Detector Circuit Diagram.



Section 6

SERVICE AND MAINTENANCE

GENERAL. We warrant that each new instrument is free from defects in material and workmanship that, properly used, it will perform in full accordance with applicable specifications for a period of two years after original shipment. Any instrument that is found within the two-year period to not meet these standards after examination by our district office, or authorized repair agency personnel, will be repaired, or, at our option, replaced without charge, except for tubes or batteries that have no warranty service.

The two-year warranty stated above attests to the quality of materials and workmanship in our products. If difficulties do occur, our service engineers will attempt to correct them in any way possible. If the difficulty cannot be corrected by use of the following service instructions, please write or phone our Service Department (see rear of instrument) for full information of the trouble and of the steps to be taken to remedy it. Be sure to mention the type and serial numbers of the instrument.

Before returning an instrument to General Radio, please write to our Service Department or district office, requesting a Returned Material Receipt. The use of this tag will ensure proper handling and return. For instruments not covered by the warranty, a purchase order should be forwarded to avoid any delay.

CLEANING AND LUBRICATION.

POTENTIOMETER. The lubrication port on the top of the potentiometer is sealed by a small screw. Remove this screw and add 20 drops of oil every three months. Recommended lubricants are Stanolil No. 35 (Standard Oil Co.) and Gulfcrest C (Gulf Oil Co.).

GEAR BOX. The gear box should not be lubricated. It will collect dirt and cause noisy operation. Lubricating bearings are used with moving parts of the recorder.

GUIDE ROD. The guide rod on which the coil slides should be cleaned with a clean soft dry cloth to ensure maximum writing-speed capability. Under no circumstances should it be oiled.

POTENTIOMETER. Clean and lubricate the potentiometer monthly with NO-OX, supplied with the potentiometer. Brush a small amount on the track and wipe off with a clean, lint-free cloth. Apply a second coat after 24 hours. If operation of the pen with constant-

level input becomes noisy, the potentiometer needs cleaning.

6.2.5 PEN. Ink should not be left in the pen for more than two days, or it will dry and clog the pen.

To clean the pen, first shake the ink from the reservoir. Fill the pen with water and remove the remaining ink from the capillary tube by running the point along an absorbant paper towel or tissue. If ink clogs the point, remove the ink with the cleaning wires provided.

6.3 OVERSHOOT AND CREEP ADJUSTMENTS.

6.3.1 GENERAL. The overshoot and creep controls are set at the factory and should not normally require adjustment, except possibly when an 80-db potentiometer is used or when the DAMPING control setting is changed appreciably.

6.3.2 OVERSHOOT ADJUSTMENT. With the 40-db potentiometer installed, and with the writing speed set at 20 in./sec, proceed as follows:

a. Apply a constant-level input to the recorder INPUT terminals, and set the pen near the top of the scale.

b. Using either the recorder's INPUT ATTENUATION control or preferably, an external attenuator, quickly decrease the level 20 db, and observe the amount of overshoot.

c. Adjust the DAMPING control for the amount of overshoot desired (1 division, 1 db on the 40-db potentiometer, is recommended).

d. Turn the CREEP control fully clockwise.

e. Using an attenuator as in step b, quickly increase the level 20 db, and observe the amount of overshoot.

f. Adjust the OVERSHOOT control so that the overshoot observed in step e equals that achieved in step c.

The above procedure may be followed with a 80-db potentiometer used in place of the 40-db unit. For 20-db potentiometers, first make the adjustments in paragraphs 6.3.2 and 6.3.3, using a 40-db potentiometer, and then adjust the DAMPING control for the desired overshoot (1 1/2 db recommended) with the 20-db potentiometer.

6.3.3 CREEP ADJUSTMENT. With the 40-db potentiometer installed, and with the writing speed set at 10 in./sec, proceed as follows:

a. Apply a constant-level input to the recorder INPUT terminals, and set the pen near the bottom of the scale.

b. Using either the recorder's INPUT ATTENUATION

GENERAL RADIO COMPANY

bly, an external attenuator, quickly in-
0 db, and observe the amount of creep.
y return of the pen to its steady-state
oot or undershoot. Adjust the CREEP
creep.

check on overshoot and creep, set the
0 in./sec, and switch in 20-db attenu-
ving that the overshoot is symmetrical
decreases in both directions, and that
turns to its steady-state value.

OOTING PROCEDURE. The follow-
required:

ohms/volt Oscilloscope
 Sine-wave oscillator

der is inoperative, the most straight-
cating the trouble is to apply a known
UT terminals and trace it through to
ssembly. The procedure is as follows:
olt, 1-kc signal to the INPUT termi-
er.

o potentiometer installed, set the IN-
ON control to 40 db. The pen should
midscale. If it does not, proceed to

input to the ac amplifier is 1 mv (refer
To apply 1 mv to the ac amplifier,
INPUT terminals, set the INPUT AT-

TENUATION switch to 60 db. Then move the pen to 0
db (as marked on the potentiometer).

d. Connect a dc voltmeter (20,000 ohms/volt) to the
output of the detector, as follows: Connect the positive
voltmeter lead to TP4 and the negative lead to ter-
minal 114. The voltmeter should indicate 1 volt. If not,
check the output of the ac amplifier by connecting an
oscilloscope to TP1 on the etched board. The signal at
TP1 should be 0.5 volt peak-to-peak, and of the same
frequency as the input signal. If the frequency is 60
cycles, check the grounding of the low INPUT terminal
to the chassis, and make sure that the chassis is con-
nected to a suitable external ground (refer to paragraph
2.1.7). If there is no signal present, check the col-
lectors of the preceding transistor stages to isolate the
faulty transistor.

e. If 1 volt is present at the detector output and the
pen still does not respond, one of the transistors in the
dc amplifier may be at fault. Check the voltages in the
dc amplifier against those given in Table 6.2. The
transistors in the dc amplifier are matched for dc char-
acteristics, and some selection may be required to find
an acceptable substitute. With a satisfactory replace-
ment, the pen will not move as the WRITING SPEED
control is switched from 3 to 1 in./sec.

The following tables lists other common troubles
and their remedies. (Refer to Figure 6.2.)

TABLE 6.1
TROUBLE-SHOOTING CHART

Symptom	Remedy
ac amplifier. Unable to get sensitivity of 1 mv.	Substitute higher- h_{fe} transistor in ac amplifier (Q102, Q105).
operation of pen with constant- ut signal.	Clean potentiometer. (Refer to paragraph 6.2.4.)
metrical waveform and overshoot.	First adjust for symmetrical overshoot (refer to paragraph 6.3). If this does not solve the problem, transistor pairs Q110, Q111 and Q112, Q113 may not be matched in cur- rent gain, h_{fe} . (Refer to Table 6.3 for replacement.)
on of Pen.	Increase DAMPING (clockwise). Check resistance of feedback coil. (Refer to Table 6.2.) Check to see that wires for drive coil and feedback coil are connected properly.
ic accuracy. Large region rvo will not balance.	Check current gain of transistors in dc amplifier. Replace transistors if necessary. (Refer to Table 6.3.)
on drive coil.	Check resistance of drive coil (refer to Table 6.2). Check transistors in dc amplifier. Replace, if necessary (refer to Table 6.3).

TYPE 1521-A GRAPHIC LEVEL RECORDER

RVICE PROBLEMS. The following serv-
ould be referred to the factory:
ment of parts on magnetic assembly (see
cluding potentiometer contact and drive
except pen holder).

- (2) Other mechanical problems in the gear box or drum and chart drive mechanism.
- (3) Electronic problems other than those listed in the trouble-shooting section.

TABLE 6.2. DC VOLTAGE AND RESISTANCE CHART

Transistor	Volts DC At Emitter*	Test Point	Volts DC**	Points (Fig. 6.1)	Ohms***
Q101	9	AT109	18	A-B	40
Q102	0.5	AT111	30	B-C	40
Q103	2.6	AT127	13	D-E	250
Q104	1.6	TP4	17	<div>Measure voltage with 20,000 ohm/volt meter, to ground unless otherwise indicated.</div> <div>*Transistor mounting orientation on etched board:<div>solder dot E near collector B •C</div></div> <div>**Voltages with pen at rest and 1 volt at detector output.</div> <div>***First unscrew and remove wires 1 through 5, Figure 6.1.</div>	
Q105	5	TP4-AT113	0.7		
Q106	1.4	TP4-AT114	1.0		
Q107	1.4	TP4-AT116	1.0		
Q108	16	col. Q1	13		
Q109	16	col. Q2	13		
Q110	16				
Q111	16				
Q112	23				
Q113	23				

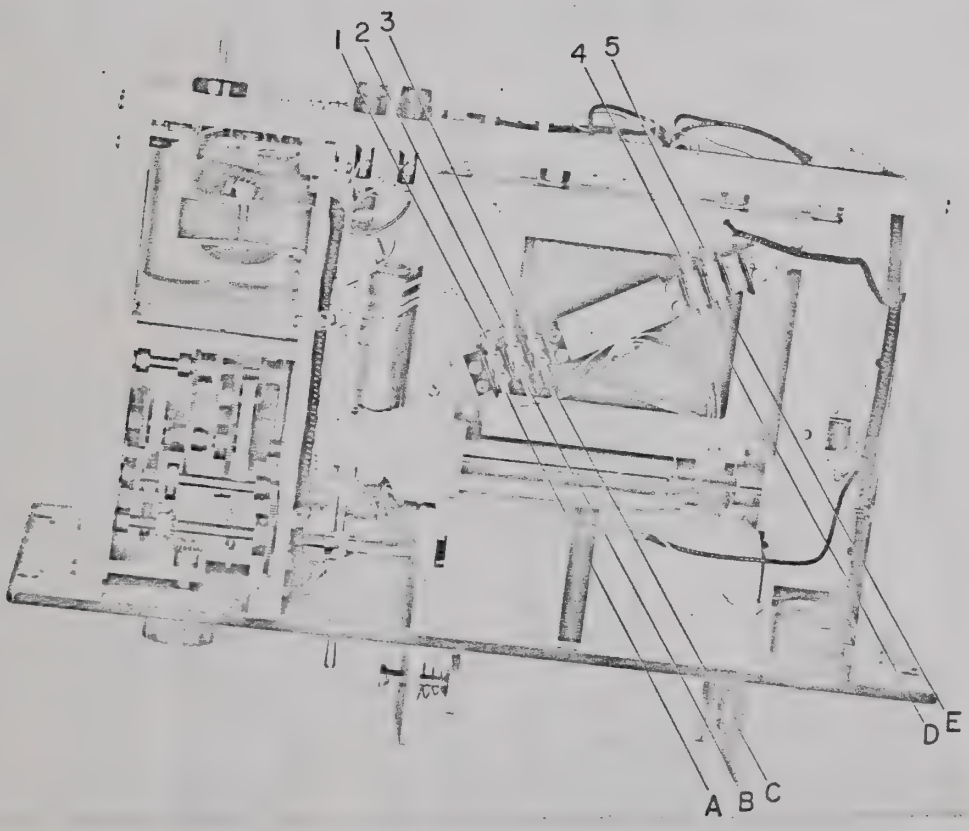


Figure 6.1. Bottom View.

TYPE 1521-A GRAPHIC LEVEL RECORDER

PARTS LIST

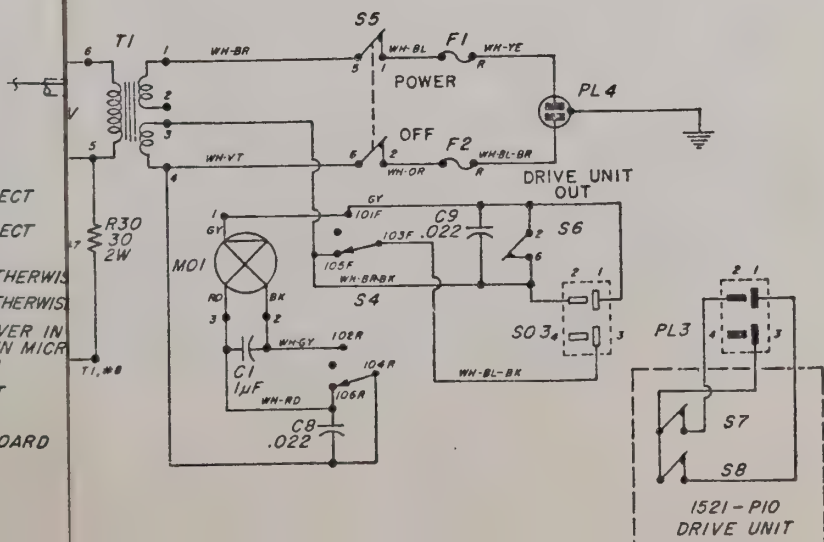
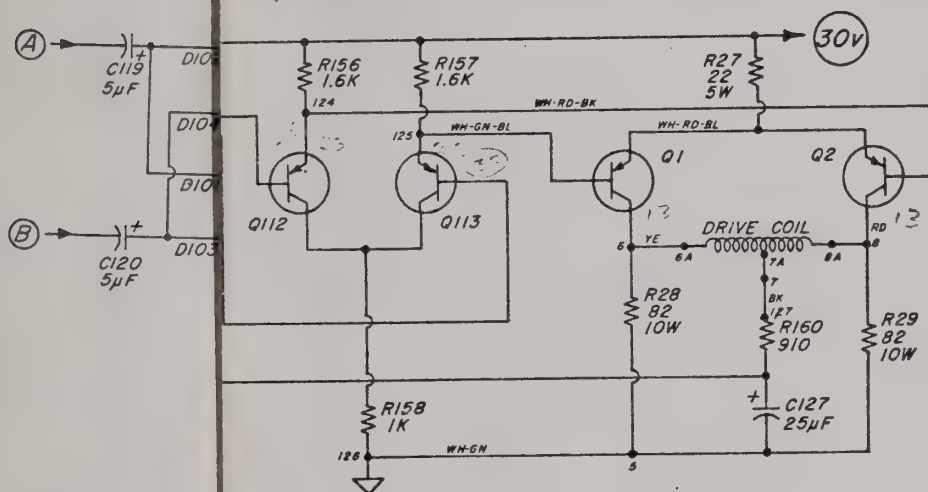
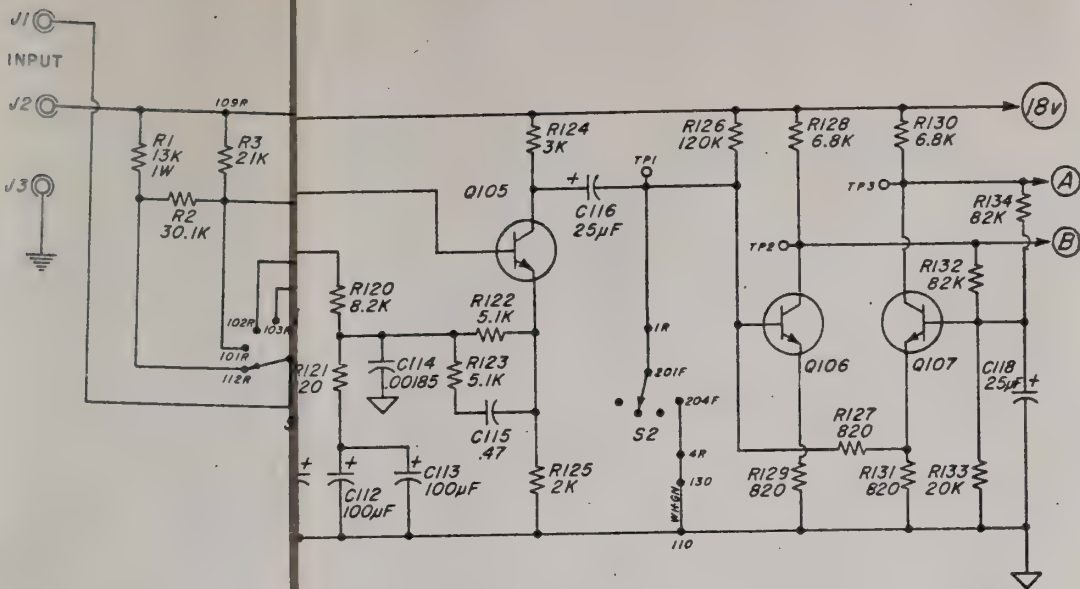
PART NO. (NOTE A)					PART NO. (NOTE A)				
RESISTORS. All resistances are in ohms, except k = kilohms, M = megohms					CAPACITORS. Capacitances are in μf unless otherwise indicated.				
1 w REF-75	R118	12 k	$\pm 5\%$	1/2 w REC-20BF	C1	1	220 vac	MOD-26-2	
1/2 w REF-70	R119	1.5 k	$\pm 5\%$	1/2 w REC-20BF	C2A	400			
1/2 w REF-70	R120	8.2 k	$\pm 5\%$	1/2 w REC-20BF	C2B	200	50 dcwv	COE-58	
1/8 w REF-60	R121	220	$\pm 5\%$	1/2 w REC-20BF	C2C	200			
1/2 w REF-70	R122	5.1 k	$\pm 5\%$	1/2 w REC-20BF	C3A	400			
1/8 w REF-60	R123	5.1 k	$\pm 5\%$	1/2 w REC-20BF	C3B	200	50 dcwv	COE-58	
1/2 w REF-70	R124	3 k	$\pm 5\%$	1/2 w REC-20BF	C3C	200			
1/8 w REF-60	R125	2 k	$\pm 5\%$	1/2 w REC-20BF	C4A	150			
1/2 w REF-70	R126	120 k	$\pm 5\%$	1/2 w REC-20BF	C4B	75	150 dcwv	COE-38	
1/8 w REF-60	R127	820	$\pm 5\%$	1/2 w REC-20BF	C4C	75			
1/4 w REF-65	R128	6.8 k	$\pm 5\%$	1/2 w REC-20BF	C5	22 μf	$\pm 10\%$	500 dcwv	COC-21NPO
1/8 w REF-60	R129	820	$\pm 5\%$	1/2 w REC-20BF	C7	22 μf	$\pm 10\%$	500 dcwv	COC-21NPO
pt.) 1521-P1	R130	6.8 k	$\pm 5\%$	1/2 w REC-20BF	C8	0.022		1000 dcwv	COC-63
pt.) 1521-P2	R131	820	$\pm 5\%$	1/2 w REC-20BF	C9	0.022		1000 dcwv	COC-63
pt.) 1521-P3	R132	82 k	$\pm 5\%$	1/2 w REC-20BF	C101	1.0	$\pm 10\%$	100 dcwv	COW-17
1521-P4-200*	R133	20 k	$\pm 5\%$	1/2 w REC-20BF	C102	5		50 dcwv	COE-57
1/2 w REC-20BF*	R134	82 k	$\pm 5\%$	1/2 w REC-20BF	C103	5		50 dcwv	COE-57
POSC-11*	R135	20 k	$\pm 5\%$	1/2 w REC-20BF					
1/2 w REC-20BF*	R136	20 k	$\pm 5\%$	1/2 w REC-20BF	C104	5 μf		50 dcwv	COE-57
1/2 w REC-20BF*	R137	250	$\pm 10\%$	POSC-11					
POSC-11*	R138	240	$\pm 5\%$	1/2 w REC-20BF	C105	100		15 dcwv	COE-46
1/2 w REC-20BF	R139	500	$\pm 10\%$	POSC-11	C106	0.001	$\pm 10\%$	100 dcwv	COW-17
POSC-18	R140	470	$\pm 5\%$	1/2 w REC-20BF	C107	100		25 dcwv	COE-35
POSW-3	R141	240	$\pm 5\%$	1/2 w REC-20BF	C108	0.47	$\pm 10\%$	100 dcwv	COW-17
1/2 w REC-20BF	R142	3.6 k	$\pm 5\%$	1/2 w REC-20BF	C109	60		25 dcwv	COE-47
1/2 w REC-20BF	R143	36 k	$\pm 5\%$	1/2 w REC-20BF	C110	5		50 dcwv	COE-57
10 w REPO-44	R144	36 k	$\pm 5\%$	1/2 w REC-20BF	C111	100		15 dcwv	COE-46
1/2 w REC-20BF	R145	9.1 k	$\pm 5\%$	1/2 w REC-20BF	C112	100		25 dcwv	COE-35
5 w REPO-43	R146	9.1 k	$\pm 5\%$	1/2 w REC-20BF	C113	100		25 dcwv	COE-35
10 w REPO-44	R147	18 k	$\pm 5\%$	1/2 w REC-20BF	C114	0.00185	$\pm 2\%$	100 dcwv	COM-5E
10 w REPO-44	R148	12 k	$\pm 5\%$	1/2 w REC-20BF	C115	0.47	$\pm 10\%$	100 dcwv	COW-17
2 w REC-41BF	R149	9.1 k	$\pm 5\%$	1/2 w REC-20BF	C116	25		50 dcwv	COE-48
1 w REC-30BF	R150	18 k	$\pm 5\%$	1/2 w REC-20BF	C118	25		50 dcwv	COE-48
1/2 w REC-20BF*	R151	18 k	$\pm 5\%$	1/2 w REC-20BF	C119	5		50 dcwv	COE-57
1/2 w REC-20BF*	R152	33 k	$\pm 5\%$	1/2 w REC-20BF	C120	5		50 dcwv	COE-57
1/2 w REC-20BF	R153	10 k	$\pm 5\%$	1/2 w REC-20BF	C121	0.22	$\pm 10\%$	100 dcwv	COW-17
	R154	10 k	$\pm 5\%$	1/2 w REC-20BF	C122	0.22	$\pm 10\%$	100 dcwv	COW-17
	R155	10 k	$\pm 5\%$	1/2 w REC-20BF	C123	0.47	$\pm 10\%$	100 dcwv	COW-17
1/2 w REC-20BF	R156	1.6 k	$\pm 5\%$	1/2 w REC-20BF	C124	0.01	$\pm 10\%$	100 dcwv	COW-17
1/2 w REC-20BF	R157	1.6 k	$\pm 5\%$	1/2 w REC-20BF	C125	1.0	$\pm 10\%$	100 dcwv	COW-17
1/2 w REC-20BF	R158	1 k	$\pm 5\%$	1/2 w REC-20BF	C126	0.01	$\pm 10\%$	100 dcwv	COW-17
1/2 w REC-20BF	R159	820	$\pm 5\%$	1/2 w REC-20BF	C127	25		25 dcwv	COE-48
1/2 w REC-20BF	R160	910	$\pm 5\%$	1/2 w REC-20BF	C128	0.1	$\pm 10\%$	100 dcwv	COW-17
1/2 w REC-20BF	R161	100	$\pm 5\%$	1/2 w REC-20BF	C129	0.1	$\pm 10\%$	100 dcwv	COW-17
1/2 w REC-20BF	R162	100	$\pm 5\%$	1/2 w REC-20BF	C130	0.022	$\pm 10\%$	100 dcwv	COP-24
1/2 w REC-20BF	R163	470 k	$\pm 5\%$	1/2 w REC-20BF					
1/2 w REC-20BF	R164	180	$\pm 5\%$	1/2 w REC-20BF					
1/2 w REC-20BF	R165	18 k	$\pm 5\%$	1/2 w REC-20BF					
1/2 w REC-20BF	R166	2 k	$\pm 5\%$	1/2 w REC-20BF					
1/2 w REC-20BF	R167	5.6 k	$\pm 5\%$	1/2 w REC-20BF					
1/2 w REC-20BF	R168	2.5 k	$\pm 10\%$	POSC-11					
1/2 w REC-20BF	R169	10 k	$\pm 5\%$	1/2 w REC-20BF					
1/2 w REC-20BF	R170	68 k	$\pm 5\%$	1/2 w REC-20BF					
1/2 w REC-20BF	R171	51	$\pm 5\%$	1/2 w REC-20BF					
1/2 w REC-20BF	R172	510	$\pm 5\%$	1/2 w REC-20BF					
1/2 w REC-20BF	R173	120	$\pm 5\%$	1/2 w REC-20BF					

DIODES (NOTE B)

D1	2RE-1001/1N3253	D105	2RED-1016/1N645
D2	2RE-1001/1N3253	D106	2RED-1016/1N645
D101	2RED-1008/1N191	D107	2REZ-1009/1N957B
D102	2RED-1008/1N191	D108	2RED-1016/1N645
D103	2RED-1008/1N191	D109	2RED-1016/1N645
D104	2RED-1008/1N191		

PARTS LIST (Cont)

37



FOR 115V OPERATION CONNECT
#1 TO #3, #2 TO #4
OR 230V OPERATION CONNECT
#1 TO #2, #3 TO #4
RESISTORS 1/2WATT UNLESS OTHERWISE SPECIFIED
CAPACITANCE VALUES ONE & OVER IN MICROFARADS, LESS THAN ONE IN MICROFARADS UNLESS OTHERWISE SPECIFIED
NOB ADJUSTMENT
SIGNAL GND ON ETCHED BOARD
CHASSIS

